FORAMINIFERAL CHARACTERISATION AND TAXONOMY OF OLIGOCENE – MIOCENE CONGO FAN DEEP SEA SUB-ENVIRONMENTS, OFFSHORE ANGOLA

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Declaration: This project, including all of its contents and data, is entirely the work of the author (unless otherwise indicated).

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ABSTRACT

The Congo Fan has been accumulating sediment since the mid-Oligocene, and is of particular interest to the oil industry due to abundant large reservoirs contained within the meandering sandy palaeochannels from largely Miocene and Oligocene deposits. The high sedimentation rates and rich benthic foraminiferal faunas also provide an interesting record of Miocene and Oligocene palaeoceanographic change in the southeast Atlantic, a stratigraphic time interval that has had no recovery from proximal ODP and DSDP Sites.

Three oil wells spanning the Upper Oligocene to Middle Miocene from the distal part of the Congo Fan (Block 31, approximately 2000 m water depth) are studied for both benthic and planktonic foraminifera using ditch cutting samples at 10 m spacing. In addition to assemblage data, $\delta^{18}O$ and $\delta^{13}C$ measurements have been obtained from *Cibicidoides* spp. for the Miocene which, along with several planktonic foraminiferal datums, provides a relatively well-constrained age model. The Oligocene sections are dominated by agglutinated benthic foraminifera and the age model is less accurate. A full taxonomy has been carried out on all foraminifera encountered, with over 150 agglutinated, 80 calcareous benthic, and 27 planktonic species described and pictured. A number of sedimentological environments contain characteristic faunas. Channel deposits are either barren or contain current-sorted calcareous specimens, levee deposits have higher abundances of transported calcareous specimens and are affected by hydrodynamic sorting, overbank deposits are dominated by high diversity *in situ* agglutinated faunas.

Oligocene sediments from the Congo Fan consist almost entirely of agglutinated foraminifera due to deposition below a locally raised CCD. A level of decreased diversity and increased abundance (the '*Scherochorella*' event) in the intra-Upper Oligocene records a probable expansion of the oxygen minimum zone associated with polar cooling. During the Early Miocene a gradual and persistent increase in the percentage of calcareous foraminifera is mirrored by increasing benthic $\delta^{13}C$, suggesting reduced bottom-water acidification and a lowering of the CCD. A dramatic shift in the shallow infaunal morphogroup (~16 Ma) indicates lower oxygen and a second episode of oxygen minimum zone expansion, which is coincident with cooling in this location and adds evidence for raised colder bottom waters. Global cooling at this time was probably responsible for increasing the strength of the polar front, and in turn strengthening offshore winds affecting an increase in upwelling and surface water productivity.

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CHAPTER 1 – INTRODUCTION

The Congo Fan is the distal component of the second largest delta system in the world, covering some 3.7 x 10^6 km^2 (Anka and Séranne 2004) and draining most of central Africa through the Congo River and its associated tributaries (see Goudie 2005). The Congo Fan is a terrigenous wedge largely built of Oligocene and Miocene sands and shales organised into thick sedimentary packages containing palaeocanyons, palaeochannels and overbank deposits (Anka and Séranne 2004; Babonneau et al. 2002; Lavier et al. 2001). These unique meandering palaeochannels contain sands that have proven to be high quality traps for migrating hydrocarbons (Evans 2002). The Congo Fan has received significant scientific attention in recent years due in part to this interest from the oil industry. However the lack of published foraminiferal studies has lead to a need for the documentation and analysis of these faunas. Moreover, our understanding of the distribution and response of micropalaeontological faunas from clastic submarine fan environments is not yet complete and has received relatively little study to date (see Lundquist et al. 1997; Jones 1999; Smith and Gallagher 2003; Dellamonica 2004; Fontanier et al. 2005; Jones et al. 2005; Jones 2006; Rogerson et al. 2006; Koho et al. 2007).

The aims and objectives of this study are therefore the following:

1. To analyse three oil wells (provided by BP) from the distal section of the Congo Fan in order to document and describe the foraminiferal faunas present, including a full taxonomical analysis.

2. To interpret as fully as possible the biostratigraphy of the sections, and attempt to tie the wells together by developing a zonation scheme based largely on benthic foraminifera.

3. To characterise the sedimentological facies in terms of their micropalaeontological content, and to provide interpretations on palaeoecological and sedimentological factors affecting these faunas.

4. To analyse the micropalaeontological signal (with the aid of stable isotope analysis where possible) in order to unravel the palaeoceanographic and palaeoclimatic history in the southeast Atlantic during the Late Oligocene – Middle Miocene.

CHAPTER 2 – PREVIOUS MICROPALAEONTOLOGICAL STUDIES

The Congo Fan has been the subject of an increasing number of earth science studies in recent literature, not least due to the increase in hydrocarbon interest in the region over the last few years (Evans 2002). Although this has lead to the publication of many geological studies (Anderson et al. 2000; Lavier et al. 2001; Anka and Séranne 2004; Broucke et al. 2004; Giresse 2005), architectural studies (Savoye et al. 2000; Babonneau et al. 2002; Sultan et al. 2004), geochemical studies (Bentahila et al. 2006) and seismic studies (Uenzelmann-Neben et al. 1997; Uenzelmann-Neben 1998), relatively little has been published on the micropalaeontology of the Congo Fan. A series of foraminiferal studies from West Africa focussed on Cretaceous and also Cenozoic outcrops in which many species were described (Chenouard et al. 1960; de Klasz et al. 1960; de Klasz and Rérat 1962a, 1962b; de Klasz et al. 1963; Graham et al. 1965; Le Calvez et al. 1971; Volat et al. 1996). Cameron (1978) studied Neogene benthic foraminifera from Sites 360 and 362 offshore Angola, basing the taxonomic work largely on comparisons from New Zealand. Seiglie and Baker (1983) described several new Cenozoic species of complex-walled agglutinated foraminifera from West Africa. Preece (1999) and Preece et al. (1999; 2000) studied Miocene benthic foraminifera from exploration wells offshore Cabinda, describing new species and palaeoenvironmental implications.

Described Oligocene faunas of agglutinated foraminifera are rather sparse. Miller and Katz (1987) recorded Oligocene to Miocene benthic faunas from the Central North Atlantic, but these assemblages were largely calcareous. The northern North Atlantic has a more complete record, with Oligocene agglutinates described from ODP Sites 985 (Kaminski and Austin 1999), 643 (Kaminski et al. 1990), 647 (Kaminski et al. 1989) and 909 (Kaminski et al. 2005; Osterman and Spiegler 1996), and from Leg 38 of the Norwegian-Greenland Sea (Verdenius and Hinte 1981). The North Sea also has a good record of Oligocene agglutinates (Charnock and Jones 1990; Gradstein et al. 1994; Gradstein and Kaminski 1989; Gradstein et al. 1988). Other locations include Site 767 of the Celebes Sea (Kaminski and Huang 1991).

This study aims to provide a complete taxonomic and palaeoenvironmental analysis of the benthic foraminifera from the distal section of the Congo Fan (fig. 3.3), with all species of agglutinated, calcareous and planktonic foraminifera photographed and described. Three papers have been produced from this project so far (Kender et al. 2006; Kender et al. in press; Kender et al. in review) dealing largely with taxonomic issues.

Many of the species identifications have been based on taxonomic works by Kennett and Srinivasan (1983), Boersma (1984), Bolli and Saunders (1985), Kohl (1985), Papp and Schmid (1985), Van Morkhoven et al. (1986), Kaminski and Geroch (1993), Jones (1994), Spezzaferri (1994) and Kaminski and Gradstein (2005), including many others (see Chapter 14). Planktonic foraminifera are not common, but consist of well-known cosmopolitan species when they occur. Calcareous benthic foraminifera are somewhat restricted to the Early-Middle Miocene and are largely cosmopolitan in nature, showing affinities to those of the Atlantic and Tethys. Agglutinated foraminifera are common from the Upper Oligocene to Middle Miocene, and show affinities with cosmopolitan Paleogene and Recent species, as well as faunas from Venezuela and Trinidad, and include several endemic species (including 4 described as new in this report – Kender et al. 2006).

CHAPTER 3 – GEOLOGY OF THE CONGO FAN

The West African margin has been depositionally active since initial rifting took place in the Early Cretaceous (Jansen et al. 1984; Nürnberg and Müller 1991), following the break-up of Gondwana and the opening of the South Atlantic Ocean (see fig. 3.1 for generalised geological column). Three phases of rifting in the Early Cretaceous (De Matos 1999; Karner and Driscoll 1999) saw the formation of deep lacustrine basins resulting in three sub-basins developing along the West African passive margin, including the Lower Congo basin (Broucke et al. 2004), and the subsequent deposition of fluvio-lacustrine and lacustrine sands and shales. With the onset of thermal subsidence in the Aptian (Karner et al. 1997), fully marine conditions developed for the first time and this period is characterised by the formation of thick evaporite deposits. Today, these evaporites form widespread diapirs throughout the overlying sediments especially in the west. During the Albian, rising sea-levels and thermal subsidence led to basin deepening and the development of a shallow carbonate sea, with associated aggradational carbonate/siliciclastic ramp sediments (Anderson et al. 2000). South Atlantic sea-floor spreading and further subsidence in the Late Cretaceous saw the onset of deep-marine conditions and the development of deep mudstones. These mudstone deposits record several phases of ocean anoxia in the Cenomanian and Maastrichtian, which led to the formation of thick black shales and ultimately the majority of source rocks for oils in the overlying sands.

During the early-middle Paleogene the Congo Basin region of the African margin received a limited supply of sediment, resulting in a condensed sequence of aggrading platform carbonates. A significant unconformity separating the Upper Eocene from the Upper Oligocene follows, and is proceeded by the onset of thick prograding terrigenous turbidite deposits that continue to the Recent, forming up to 3 km of sediment (the Congo Fan, fig. 3.2). Séranne and Abeigne (1999) show that the unconformity before this time was a result primarily of moving surface and intermediate waters causing an erosional surface on the shelf and continental slope, possibly due to changes in oceanic circulation caused by the onset of Antarctic glaciation (Lavier et al. 2001). The reason for the subsequent deposition of the Congo Fan during the Oligocene is unclear and has been attributed to several causes. Increased sediment supply feeding an ancient Congo River has been suggested (Bond 1978; Walgenwitz et al. 1990, 1992) due to tectonic uplift in the South African region at this time. Anka and Sérranne (2004) have suggested that global cooling may be linked to the stratigraphic shift, while Anderson et al. (2000) has linked the event with lowering sea-levels at this time. Most recently, Stankiewicz and de Wit (2006) suggested that the Congo River actually flowed east before this time, draining Central Africa into the Indian Ocean, and

this appears the most likely explanation. The uplift associated with the East African Rift system in the Oligocene may well have forced central Africa to drain west.

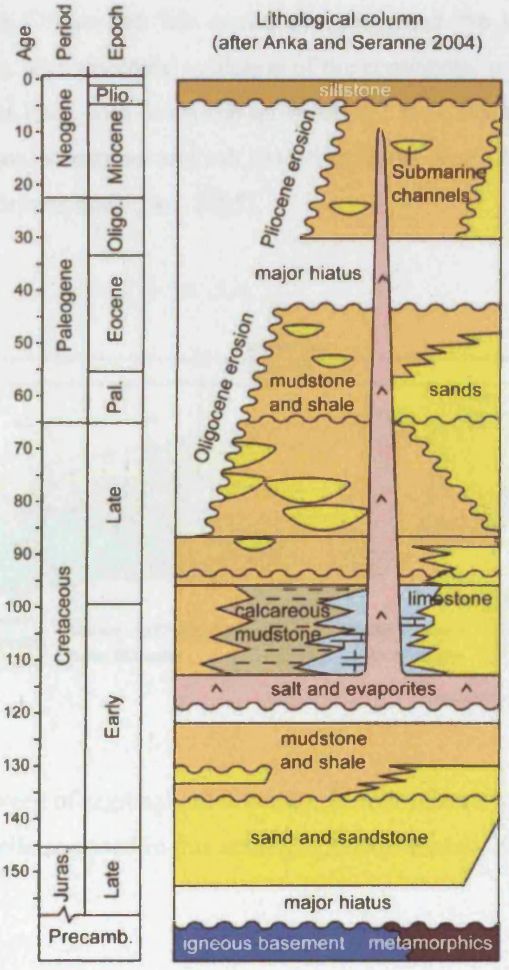


Figure 3.1 Generalised geological column for the Lower Congo basin, West African passive margin (Anka and Seranne 2004). The Congo Fan has been depositionally active since the mid-Oligocene.

The Congo Fan itself consists of shale and sand overbank and channel-levee deposits, with a well-developed deep canyon cutting the continental shelf and slope (Savoye et al. 2000; Babonneau et al. 2002; Anka and Séranne 2004). The sedimentation of the fan has been shown

by Lavier et al. (2001) to increase up to a peak in the Langhian (around 15Ma) in the offshore Angola section of the fan (close to the studied section in this study), with only a steady increase up to the present in the offshore Congo area further to the north. This is probably caused both by climatic changes, and a migrating depocentre from the south to north in the mid-Miocene. Sedimentation of the Congo Fan has continued throughout the late Miocene to Recent as a progradational wedge. The structural evolution of the continental margin has largely been driven by increased sediment load, with down-dip movement of fault blocks along the Aptian salt in the east, and compressional structures and salt diapirism in the west (Anderson et al. 2000; Cramez and Jackson 2000; Séranne and Anka, 2005).

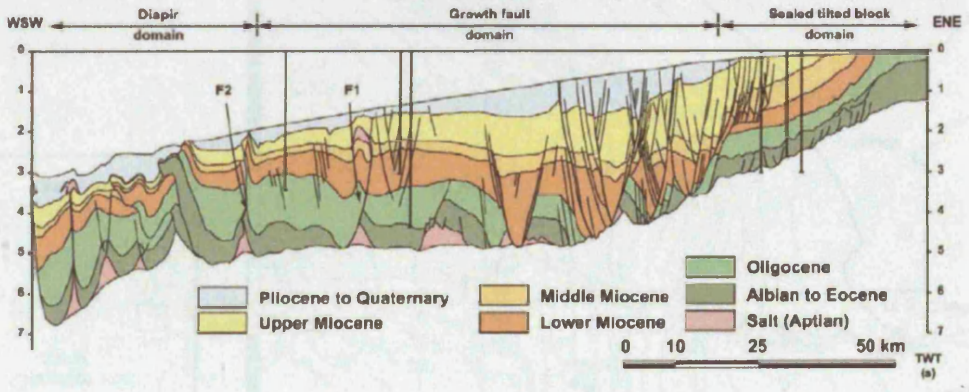


Figure 3.2 Line drawing of regional cross section from a seismic survey approximately 100 km to the south of the wells analysed in this study, which are around 200 km offshore Angola (from Broucke et al. 2004).

The wells in this study (figs 3.3, 3.4 and 3.5) largely span the Oligocene to Middle Miocene distal section of the turbiditic fan. The Upper Oligocene section forms the majority of recovery, consisting of predominantly black muds and silts with interbedded sandy horizons, and continuing into the Lower Miocene passing through large sand/silt bodies interpreted as submarine palaeochannels. The foraminifera are almost entirely agglutinated, and are present in most samples at medium to low abundances. The diversity ranges from medium to low, with significant faunal variation possibly related to productivity fluctuations.

The Lower and Middle Miocene silts and muds (analysed largely from well Plutao-1) contain gradually more calcareous and planktonic foraminifera as well as persistent agglutinated forms. The diversity and abundance is high, and shows significant variation in calcareous content which could be related to fluctuations in the CCD during the Middle Miocene. Sedimentation rates over this interval are somewhat reduced. Faunas become more diverse and reveal typical Middle Miocene calcareous and agglutinated foraminifera, along with some persisting typical Palaeogene forms (see Chapter 14 – Taxonomy).

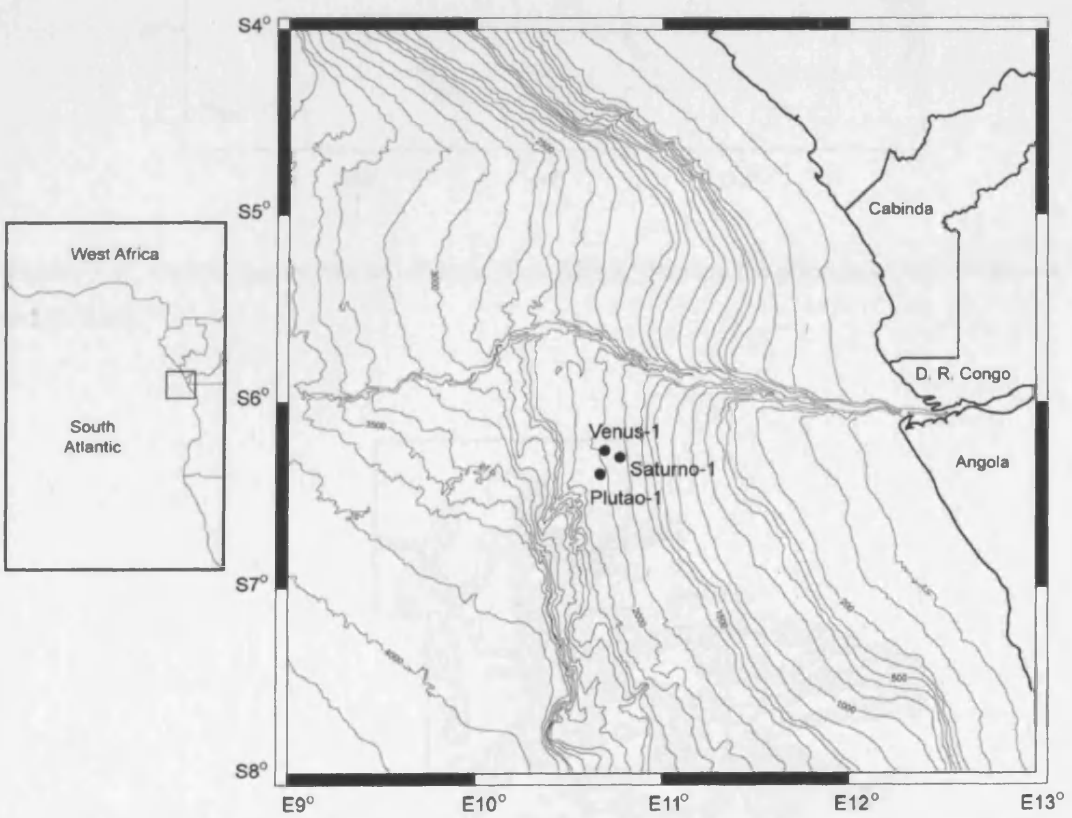


Figure 3.3 Bathymetric map of the Congo Fan, showing the location of wells analysed in this study.

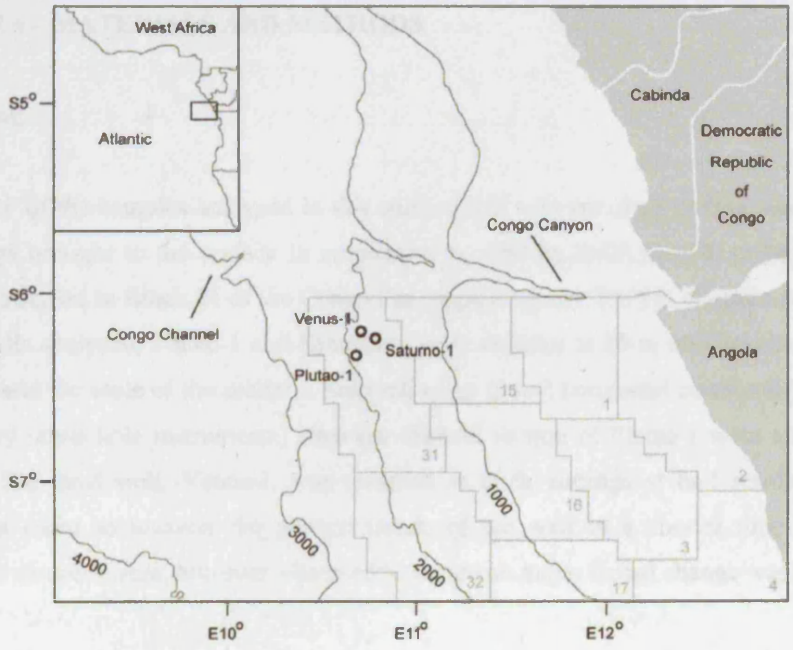


Figure 3.4 Lacation map of Blocks offshore West Africa, showing the position of wells analysed in this study.

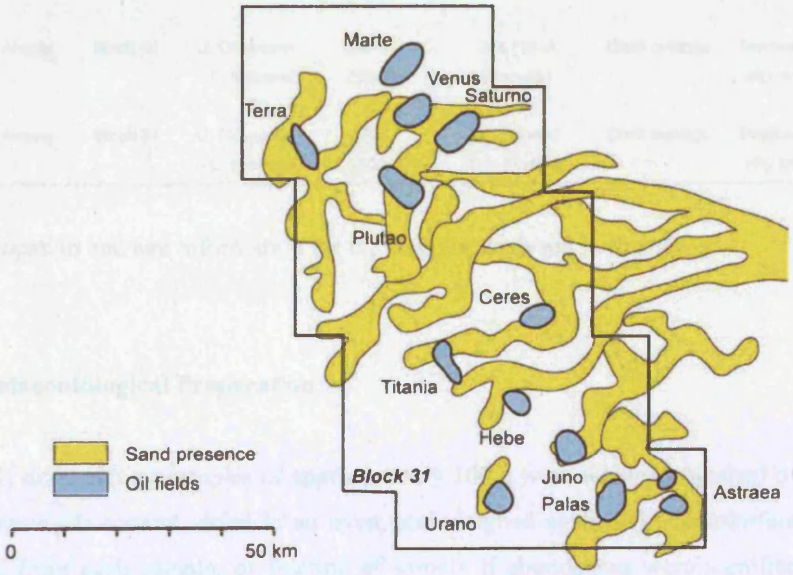


Figure 3.5 Block 31 oil fields (including Plutao-1, Saturno-1, Venus-1 analysed in this study) and sand presence locations.

CHAPTER 4 – MATERIALS AND METHODS

4.1 Sampling

The majority of the samples analysed in this study (table 4.1) are ditch cutting samples (small rock cuttings brought to the surface in suspension by drilling fluid), and have been collected from 3 wells drilled in Block 31 of the Congo Fan (approximately 200 km offshore Angola). The first two wells analysed, Plutao-1 and Saturno-1, were sampled at 10 m intervals due to sample availability and the scale of the sections. Sidewall cores (small horizontal cores collected at high resolution by down-hole instruments) from the channel section of Plutao-1 were also available for study. The third well, Venus-1, was sampled as ditch cuttings at half resolution (20 m intervals) in order to uncover the general trends of the well in a shorter time period. All intermediate samples were, however, observed to ensure no major faunal change was missed.

Well Name	Country	Location	Age	Depth (md)	No. samples	Sample type	Lithology
Plutao-1	Angola	Block 31	U. Oligocene – Langhian	2760 – 4270 m	152 (10 m intervals)	Ditch cuttings	Predominantly turbiditic silty shales with sands
Plutao-1	Angola	Block 31	U. Oligocene – Aquitanian	3392 – 3545 m	38 (2 – 6 m intervals)	Sidewall cores	Channel sands, sandy silts and silts
Saturno-1	Angola	Block 31	U. Oligocene – L. Miocene	2875 – 5000 m	214 (10 m intervals)	Ditch cuttings	Predominantly turbiditic silty shales with sands
Venus-1	Angola	Block 31	U. Oligocene – L. Miocene	3095 – 4500 m	72 (approx. 20 m intervals)	Ditch cuttings	Predominantly turbiditic silty shales with sands

Table 4.1 Location and age information for the samples analysed in this study.

4.2 Micropalaeontological Preparation

For Plutao-1, ditch cutting samples of approximately 100 g were weighed, washed over a 63 μm sieve to remove silt content, dried in an oven, and weighed again. All foraminifera > 125 μm were picked from each sample, or fraction of sample if abundances were significantly higher than 300, sorted into species, glued onto cardboard reference slides and counted (see Appendix 1 and 2). Sidewall core samples were subject to the same procedure as above, with the entire available sample used (see Chapter 6). Samples are stored in the Postgraduate Unit of

Micropalaeontology at UCL. Smaller fractions were not included in the analysis as the fossilisation potential of small specimens is even lower than larger ones, thus introducing a greater element of bias into results. Photographic images were taken using JEOL JSM-648OLV SEM at University College London, after coating specimens in gold. Image brightness and contrast was adjusted using Adobe Photoshop. Type specimens of new species described herein are deposited in the Department of Palaeontology, Natural History Museum, London, and in the author's collection at UCL.

For Saturno-1 and Venus-1, ditch cutting samples were processed and picked by RPS Timetrax (Surrey) and delivered to UCL for temporary examination. Information on washed sample weights and fractions picked was also given, and specimens were provided loose in each slide. All specimens in each analysed sample were then identified and counted (see Appendix 3 and 4).

4.3 Isotope Analysis

The Miocene section of Plutao-1 (2800 – 3420 m) contained persistently occurring calcareous benthic foraminifera, and was therefore suitable for $\delta^{18}O$ and $\delta^{13}C$ isotopic analysis. Due to the scarcity of benthic foraminifera in some samples, oxygen and carbon isotopes were obtained from *Cibicidoides* spp. (*C. mundulus* and *C. pachyderma* were preferentially used where available); 2-5 specimens > 250 μm were taken where possible. Crushed specimens were then immersed in 3 % hydrogen peroxide for 30 min, ultrasonicated in methanol for 15 s, excess residue and liquid removed, and dried at 45 °C. Stable isotope analysis was conducted using a ThermoFinnigan MAT 252 and coupled carbonate preparation device at Cardiff University, with an external reproducibility of ≤ 0.08 ‰ for $\delta^{18}O$ and reported on the VPDB scale. Values of $\delta^{18}O$ recorded from *Cibicidoides* spp. have been adjusted by +0.64 ‰ to align them with equilibrium calcification at given temperature and $\delta^{18}O_{sw}$ (Shackleton 1974).

4.4 Faunal Analysis

For Plutao-1, sand percentage was obtained by subtracting the weight of the sample containing least sand (a very low value) from all samples, giving the remaining weight as a percentage of the total unwashed sample. Absolute abundance was calculated by dividing the number of foraminifera picked from each sample by the fraction picked, and then dividing by the number of grams originally sampled (around 100 g for each sample) to obtain specimens per gram. For

Saturno-1 and Venus-1 dried sample weights were the only data given, and so 'specimens per gram' refers to dried weight only (less < 63 μm fraction).

4.5 Morphogroup Analysis

Jones and Charnock (1985) first proposed subdividing agglutinated foraminifera into morphogroups based on gross morphology relating to life position and feeding habit, whilst Corliss (1985) found a similar link in live deep-sea calcareous forms. This concept has since been developed for agglutinated foraminifera by Jones (1999) and Jones et al. (2005) with the use of three groups, and by Nagy (1992), Nagy et al. (1995, 1997), van den Akker et al. (2000) and Kaminski et al. (2005) with an expanded set of morphogroups which are followed in this study (fig. 4.1). The foraminifera are subdivided on their generic classification alone. Care has been taken however to make sure each individual species matches the morphology (as some genera exhibit significant variation). Morphogroup classification can be viewed as an oversimplification for detailed analysis (Smart 2002), but the agreement with results from Correspondence Analysis in this report (see Correspondence Analysis Results, Chapters 5-8) generally supports this method. It is worth noting that the link between high infaunal proportions and low oxygen conditions is well documented (e.g. Jorissen et al. 1995; Kaminski et al. 1995; Preece et al. 1999).

The calcareous foraminiferal morphological link with life position is better constrained and has been analysed by many authors (e.g. Corliss 1991; Kaiho 1994), with the classification followed in this study (fig. 4.2) from Corliss (1991). This classification is based on live modern species from the northwest Atlantic Nova Scotian continental margin and, where present, extinct species have been approximated to groups based on generic affinities and morphology. A separate classification for calcareous foraminifera is used because this group has been better constrained to life position using modern analogues.

4.6 Statistical Analysis

The data collected in this project has been analysed statistically in an attempt to support and enhance the interpretations given. For diversity measures, in addition to simply giving the number of species counted per sample, an attempt to find the relative diversity has been made using Fisher's alpha, and this is compared with other diversity measures in this section. Assemblages have been interpreted from simple plots of species occurrence with depth, with

MORPHO-TYPE	TEST SHAPE	MAIN GENERA	MORPHO-GROUP	LIFE POSITION	FEEDING HABIT	ENVIRONMENT
	Tubular	*Nothia* *Rhabdammina* *Rhizammina* *Bathysiphon* *Kalamopsis* *Aschemocella* *Hyperammina*	M1	Erect epifauna	Suspension feeding	Tranquil bathyal and abyssal with low organic matter flux
	Globular	*Psammosphaera* *Saccammina* *Pseudosphaerammina* *Placentammina*	M2a	Shallow infauna	Suspension feeding - Passive deposit feeding	Bathyal and abyssal
	Rounded trochospiral and streptospiral	*Budashevaella* *Cribrostomoides* *Recurvoides*	M2b	Surficial epifauna	Active deposit feeding	Shelf to deep marine
	Planoconvex trochospiral	*Conotrochammina* *Trochammina* *Conglophragmium* *Trochamminoides* *subcoronatus* *Caudammina*				
	Elongate keeled	-	M2c	Surficial epifauna	Active deposit feeding	Shelf to marginal marine
	Flattened trochospiral	*Trochamminoides* *Ammosphaeroidina*	M3a	Surficial epifauna	Active and passive deposit feeding	High energy lagoon and estuary
	Flattened planispiral and streptospiral	*Glomospira* *Ammodiscus* *Paratrochamminoides* *Lituotuba* *Spiropsammina*				
	Flattened irregular	*Ammolagena* *Popovia* *Discamminoides* *Ammomarginulina*	M3b	Surficial epifauna	Passive deposit feeding	Upper bathyal to abyssal
	Rounded planispiral	*Cyclammina* *Haplophragmoides* *Reticulophragmium* *Glaphyrammina*	M4a	Surficial epifauna - Shallow infauna	Active deposit feeding	Inner shelf and upper bathyal
	Elongate subcylindrical	*Karreriella* *Textularia earlandi* *Karrerulina* *Jaculella* *Pseudonodosinella*	M4b	Deep infauna	Active deposit feeding	Inner shelf to upper bathyal with increased organic matter flux
	Elongate tapered	*Valvulina* *Hormosina* *Reophax* *Verneuilina* *Reophanus* *Subreophax* *Eggerelloides* *Scherochorella*				

Figure 4.1 Morphogroup analysis for agglutinated foraminifera followed in this study, showing the taxonomic lumping with associated life position, feeding habit and environment (after Nagy et al. 1997; van den Akker et al. 2000).

morphogroup and diversity changes, and statistically using Correspondence Analysis (CA). Principal Components Analysis is also compared to CA in this section. These statistical techniques are illustrated below to give an understanding of the data processing method. The justification for choosing each of the methods is also given. All analyses in this study were computed using the software of Hammer et al. (2005).

Epifauna **0 – 1 cm**	**Shallow Infauna** **0 – 2 cm**	**Intermediate Infauna** **~ 1 – 4 cm**	**Deep Infauna** **> 4 cm**
Cibicides lobatulus	*Brizalina* sp.	*Cibicidoides bradyi* (?)	*Chilostomella oolina*
Cibicides sp.	*Bulimina* sp.	*Melonis barleeanum*	*Florilus labradorica*
Cibicidoides kullenbergi	*Lenticulina* sp.	*Pullenia quinqueloba*	*Fursenkoina* sp.
Cibicidoides spp.	*Pseudonodosaria* sp.	*Pullenia simplex*	*Globobulimina affinis*
Discorbis williamsoni	*Pullenia bulloides*		*Nonion grateloupi*
Hoeglundina elegens	*Robertina bradyi*		*Nonionella turgida*
Planulina sp.	*Trifarina* sp.		
Planilina wuellerstorfi	*Uvigerina peregrina*		
Miliolids			

Figure 4.2 Reproduction of the morphogroups and associated species described in Corliss (1991). Samples are box cores taken at 200 – 3000 m depth transect from the Nova Scotian continental margin. 'Live' Rose Bengal stained species only.

4.6.1 Fisher's Alpha

A number of diversity measures can be used to attempt offsetting the bias resulting from counting a different number of individuals for each sample. Ideally we would count the same number of specimens (say 300), and then a direct comparison of species diversity could be made from the raw data. However when a sample is prepared it is necessary to pick out all of the specimens in the fraction of sediment used, in order to eliminate error in selectively choosing which specimens to pick.

Hayek and Buzas (1997) describe a variety of diversity indices used to obtain diversity measures in natural populations, and recommend Fisher's alpha for its ease of calculation, and results being as reliable as any other method (see fig. 4.3 for comparisons). Hammer and Harper (2006) note that this index performs well in practice even when the natural population is not a log series. This probably explains why it is the favoured choice of many workers (e.g. Kuhnt et al. 2002;

Gooday and Hughes 2002; Murray and Pudsey 2004). Furthermore as, in this study, the average number of specimens counted for Plutao-1 is over 200 per sample and for Saturno-1 and Venus-1 over 100, there is only a small expectation of significant sampling bias.

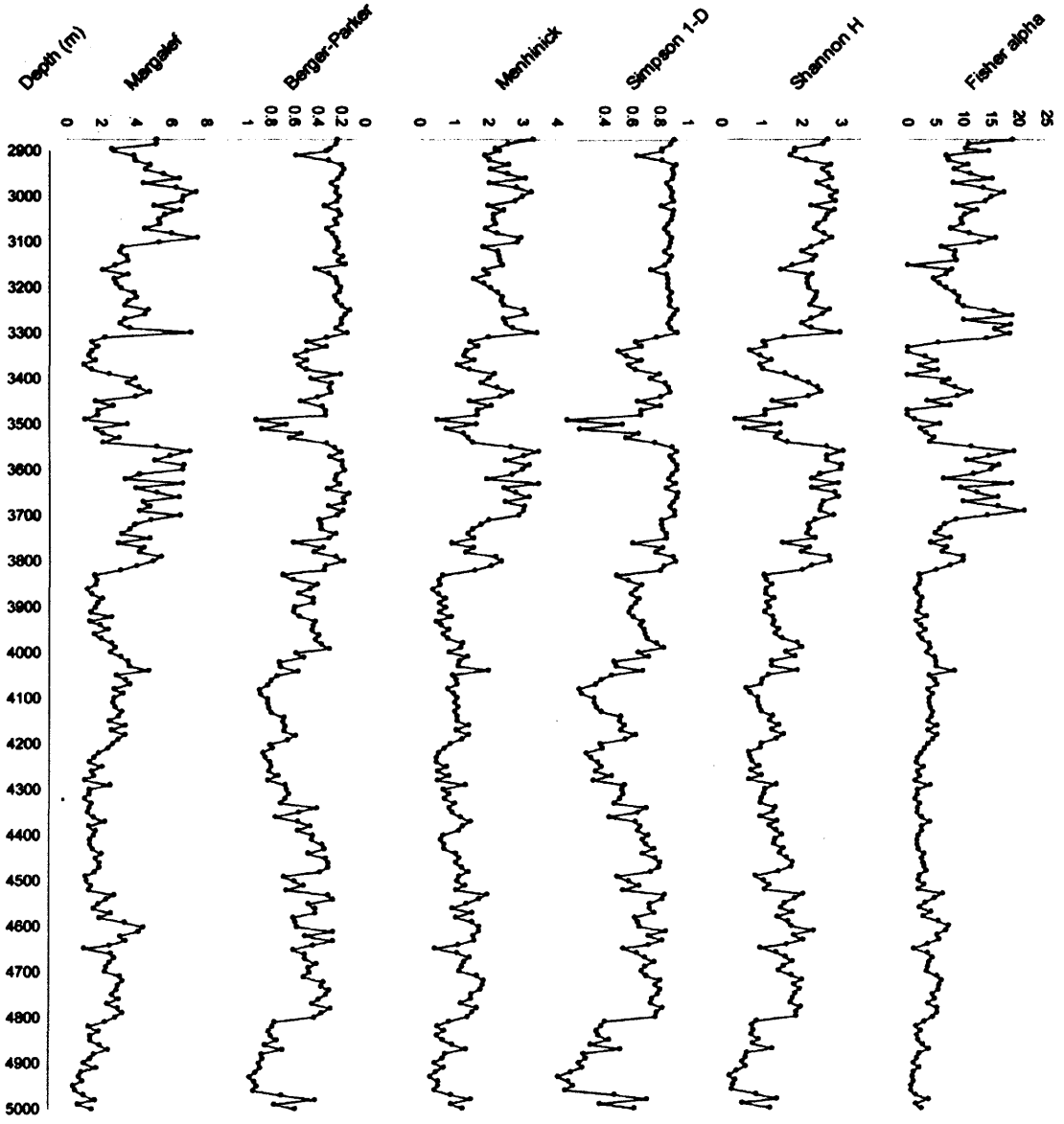


Figure 4.3 Comparison of different diversity measures for the same data (well Saturno-1). A broadly similar pattern emerges from each analysis, although variations between methods can be seen.

Fisher's alpha (Fisher et al. 1943) attempts to predict the number of species in a population that are represented by 1 individual, 2 individuals and so on, from N (the number of specimens counted) and S (the number of species encountered). It does this by making the assumption that the population is represented as a log series:

αx = number of species represented by 1 individual

$\alpha x^2/2$ = number of species represented by 2 individuals

$\alpha x^n/n$ = number of species represented by n individuals

To find alpha we use Fisher's relationship:

$$\frac{N}{S} = \frac{(e^{S/\alpha} - 1)}{S/\alpha}$$

The solution for α is iterative and so a computer program is needed to obtain it.

To find x we use Fisher's simple equation:

$$x = \frac{N}{N + \alpha}$$

If the sample size N is large enough, x will be close to 1 and α will be a good approximation of the number of species represented by 1 specimen on its own.

If x falls below 0.5 then meaning in the result is lost for biological populations (Williams 1943). If x falls below about 0.61 then α becomes greater than S which is also unacceptable (Hayek and Buzas 1997).

For a natural population, a large number of species in a sample will be represented by just 1 specimen, and so this value is a good indication of true diversity. Therefore the values for αx are obtained for each sample and plotted against depth to give a more accurate indication of how diversity changes down the well (fig. 4.4). Since each sample is given the same log series distribution (fig. 4.5), αx is independent of sample size.

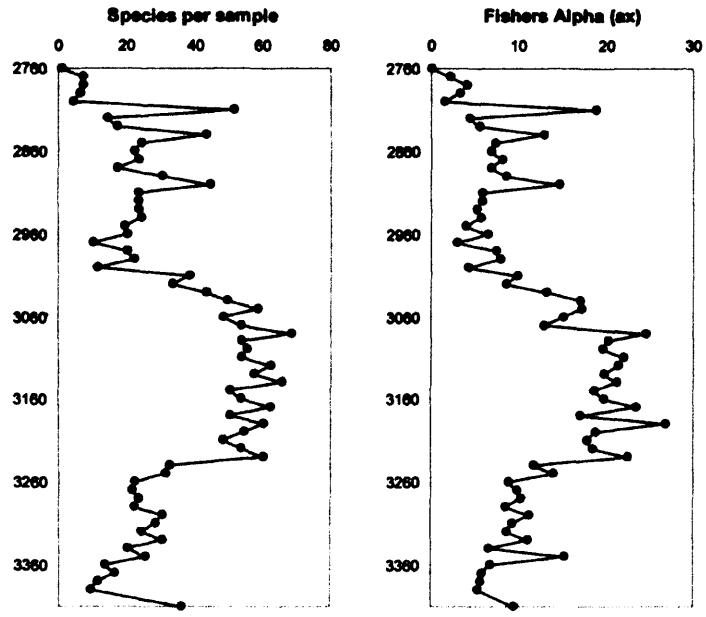


Figure 4.4 Graphs showing the number of species counted against depth, and Fisher's αx against depth respectively, for the Miocene section of Plutao-1. Although the general shape of the graphs is similar, important fine-scale adjustments can be picked out (e.g. at depth 3350 m).

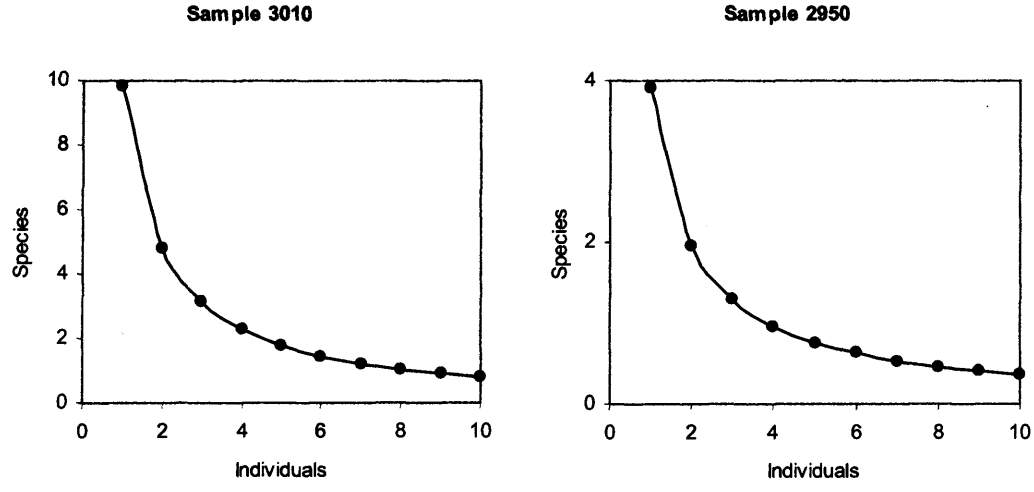


Figure 4.5 Graphs showing the number if species represented by increasing number of individuals for samples 3010 m and 2950 m respectively (Plutao-1), as calculated using Fisher's alpha diversity equation. Although the number of species differs between samples, the log series distribution is similar and so the number of specimens counted in each sample does not affect the value of αx (the number of species represented by 1 individual).

A quick visual analysis of the raw data against alpha diversity results (fig. 4.4) shows that, as expected, the raw data is good enough to give an acceptable indication of how diversity changes down the well (due to the large sample sizes used), but useful small-scale adjustments are made by the technique.

4.6.2 Principal Components Analysis

Principal Components (PCA) analysis (Hotelling 1933) is a common technique used for finding patterns in multivariate data for which plotting the multidimensional dataset on a single graph is not possible. Many authors have used the technique to help establish faunal assemblages in micropalaeontological studies (e.g. Schmiedl et al. 1997; Kuhnt et al. 1999; Fontanier et al. 2005). The following is an explanation of PCA taken from Smith (2002).

Covariance matrix

The first step is to find the covariance between all dimensions. The variance of a single set of data X can be calculated by:

$$\mathrm{var}(X) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}$$

which is the sum of each value in the data set, with the mean subtracted and squared then divided by the total number of data points minus 1.

The covariance between two sets of data X and Y can be calculated by:

$$\mathrm{cov}(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{n-1}$$

The covariance C between n sets of data can be placed in a covariance matrix:

$$C^{n\times n} = (c_{i,j}, c_{i,j} = \mathrm{cov}(Dim_i, Dim_j))$$

So if we have 3 rows of data x, y and z, the covariance matrix will be:

$$C = \begin{pmatrix} \text{cov}(x,x) & \text{cov}(x,y) & \text{cov}(x,z) \\ \text{cov}(y,x) & \text{cov}(y,y) & \text{cov}(y,z) \\ \text{cov}(z,x) & \text{cov}(z,y) & \text{cov}(z,z) \end{pmatrix}$$

Eigenvectors and eigenvalues

The next step is to find the eigenvectors and eigenvalues for the matrix. This technique is iterative and so a computer program is needed to obtain the results.

An *eigenvector* is a single column vector x through the covariance matrix A that, when multiplied by the matrix, gives a new vector that is simply an integer multiple λ of the original. So that:

$$Ax = \lambda x$$

The *eigenvalue* will be λ.

For an n x n matrix there are n eigenvectors, and each single line vector will have n rows. All eigenvectors will be perpendicular to each other.

The resulting eigenvectors are scaled so that they have a length of 1, and put into a matrix that will have n x n dimensions. The eigenvectors are listed in order of the highest eigenvalues to form a feature vector:

$$FeatureVector = (eig_1\ eig_2\ eig_{3...}\ eig_n)$$

The first eigenvector will be able to account for the largest variation within the data, the second eigenvector for the next largest, and so on (fig. 4.6). It is this property that gives PCA its power in analysing multivariate data sets.

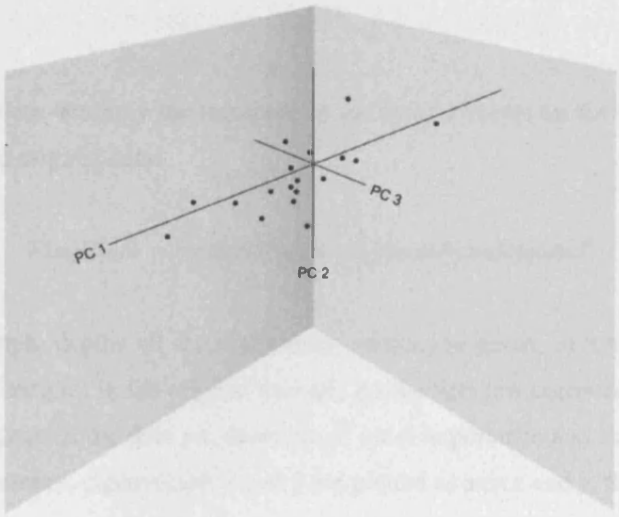


Figure 4.6 Schematic diagram showing a hypothetical spread of data in a 3-dimensional plane. PC1 (Principal Component 1) accounts for the greatest variance, PC 2 the next, and PC 3 the least. If PC1 and PC2 were plotted on a flat surface the information from PC3 would be lost.

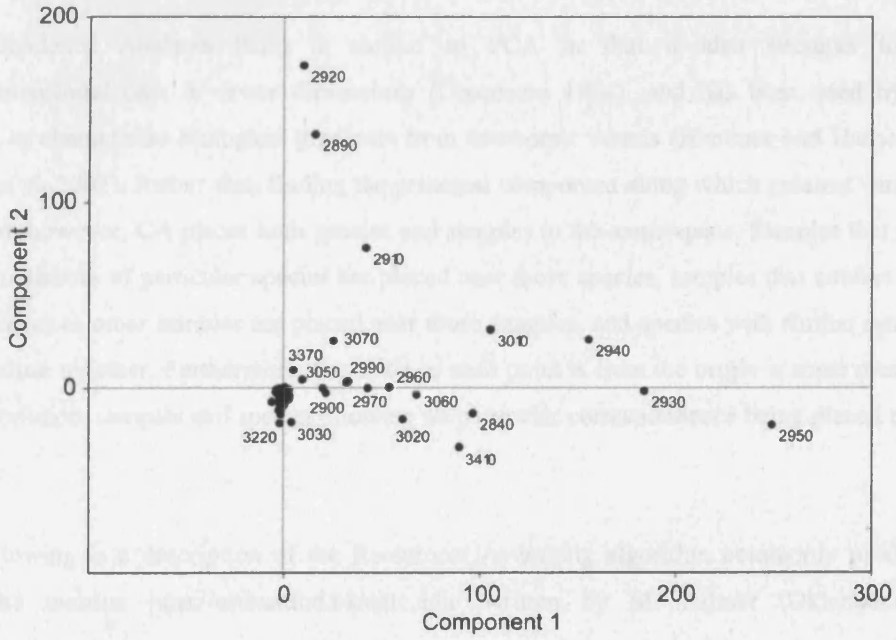


Figure 4.7 Graph showing the values for the two principal components of samples 2760 – 3410 m for well Plutao-1. The majority of the variance is contained within component 1.

Final data set

To obtain the final data, multiply the transpose of the feature vector on the left by the transpose of the mean-adjusted original data:

$$FinalData = FeatureVector^{T} \times MeanDataAdjusted^{T}$$

For each of the sample depths all the eigenvector values are given, of which there will be as many as there were samples in the original data set. As the first few eigenvectors account for the majority of the variance in the data set, these are of most importance and can be plotted against each other. If, for instance, eigenvectors 1 and 2 are plotted as axis x and y, then all of the sample depths can be seen as compared solely in terms of the vectors chosen. Figure 4.7 shows eigenvalues 1 against 2 for depths 2760 – 3410 m in well Plutao-1. Notice how most of the variation is contained within Component 1.

4.6.3 Correspondence Analysis

Correspondence Analysis (CA) is similar to PCA in that it also attempts to show multidimensional data in fewer dimensions (Greenacre 1984), and has been used by many authors to characterise biological gradients from taxonomic counts (Hammer and Harper 2006; Kuhnt et al. 2002). Rather than finding the principal component along which greatest variance is apparent, however, CA places both species and samples in the same space. Samples that contain high abundances of particular species are placed near those species, samples that contain similar assemblages to other samples are placed near those samples, and species with similar ranges are placed close together. Furthermore, the distance each point is from the origin is some measure of this correlation, samples and species showing no particular correspondence being placed near the origin.

The following is a description of the Reciprocal Averaging algorithm commonly used, taken from the website http://ordination.okstate.edu/ written by M. Palmer (Oklahoma State University).

In the initial instance, random numbers are assigned to all of the species, termed the trial *species scores K*. Trial *sample scores L* are then calculated from the weighted average of these using x_{ij}, or the abundance of each species j in each sample i:

$$L_i = \frac{\sum(x_{ij}K_j)}{\sum(x_{ij})}$$

New species scores are then calculated from the weighted average of the sample scores:

$$K_j = \frac{\sum(x_{ij}L_i)}{\sum(x_{ij})}$$

All the species and sample scores are standardised by subtracting the mean and dividing by the standard deviation. These three steps are repeated until there are no more changes between successive iterations.

This procedure results in the first axis scores for each species and sample. The proceeding axes are obtained in a similar way with extra steps to ensure each axis is perpendicular to the others in a similar way to PCA.

Discussion

PCA places samples in species space, and vice versa, whereas CA attempts to place both species and samples in the same space. This allows a direct comparison of both species and samples as they are both depicted as a point, and is therefore more useful for analysing abundance data in taxonomic populations. Figure 4.8 shows results of CA from the Miocene section of well Plutao-1, and contains samples and species on the same axes.

As pointed out by Hammer and Harper (2006), CA is also good at ordering populations that show a unimodal response to a particular environmental gradient, rather than a linear response that PCA infers. This means that particular species will have certain oxygen tolerances, for example, and decrease in abundance either side of this optimum rather than simply increasing indefinitely as the oxygen increases. This causes CA to be the most appropriate statistical analysis for taxonomic count data.

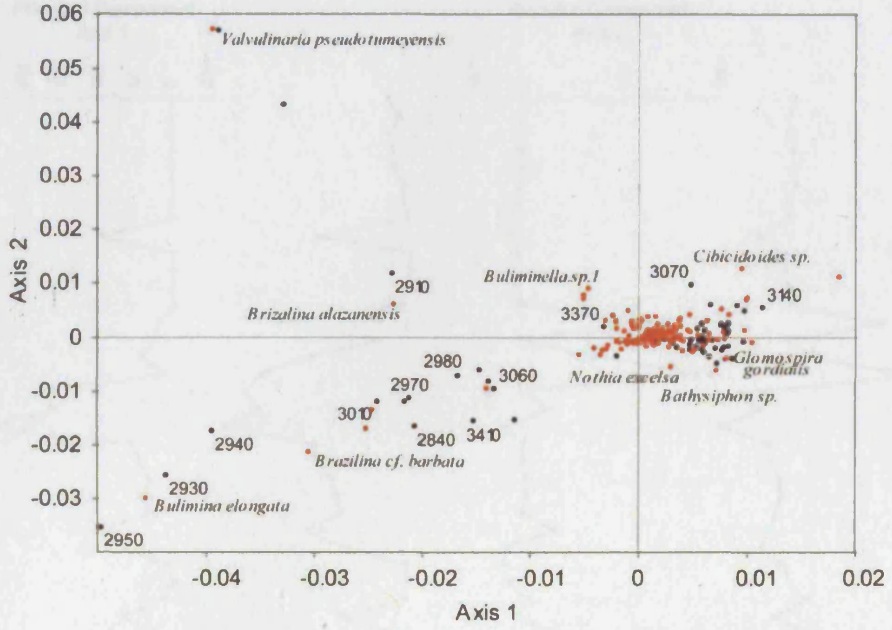


Figure 4.8 Results of CA for the Miocene section of well Plutao-1, showing the scores of components 1 and 2 for both species and samples. It is useful that they are plotted on the same graph. Species placed close to other species and samples show strong correspondence with each other.

The results from PCA and CA for the data in this study do not vary drastically but pick out similar response curves, which is to be expected from results of different techniques attempting to reveal the dominant features in the same data set. Figure 4.9 shows the results of the first and second components for both PCA and CA for data from the Miocene section of well Plutao-1, where CA seems to be picking up more fine-scale variation.

It has been noted that the first axis in CA represents some dominant palaeoecological gradient, and the second and third axes possibly minor ecological gradients. This has been demonstrated for instance by Hammer & Harper (2006) who, using the data set of Culver (1988), showed that CA arranges the samples in order of depth along axis 1 (fig. 4.10). Axis 1 in this example is thus a measure of water depth. In deep-sea environments (the subject of this study) gradients such as depth, salinity and temperature are not thought to significantly affect faunas, and so we would expect oxygen levels / organic food matter and substrate and energy fluctuations to be the overriding factors affecting assemblages.

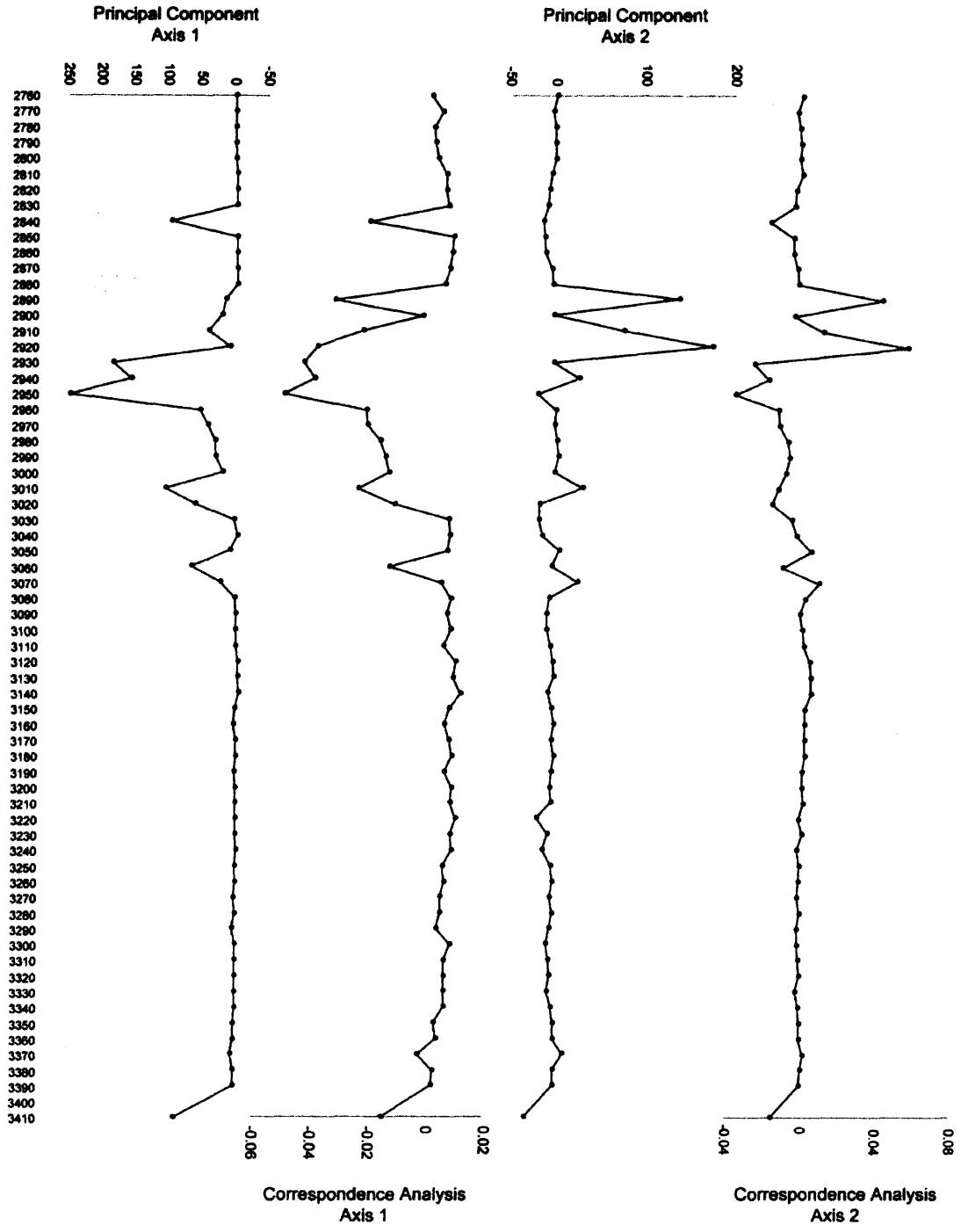


Figure 4.9 Results of PCA and CA for the Miocene section of Plutao-1, showing components 1 and 2 for sample depths. The results are similar for the two analyses, even though the procedures for obtaining them are different.

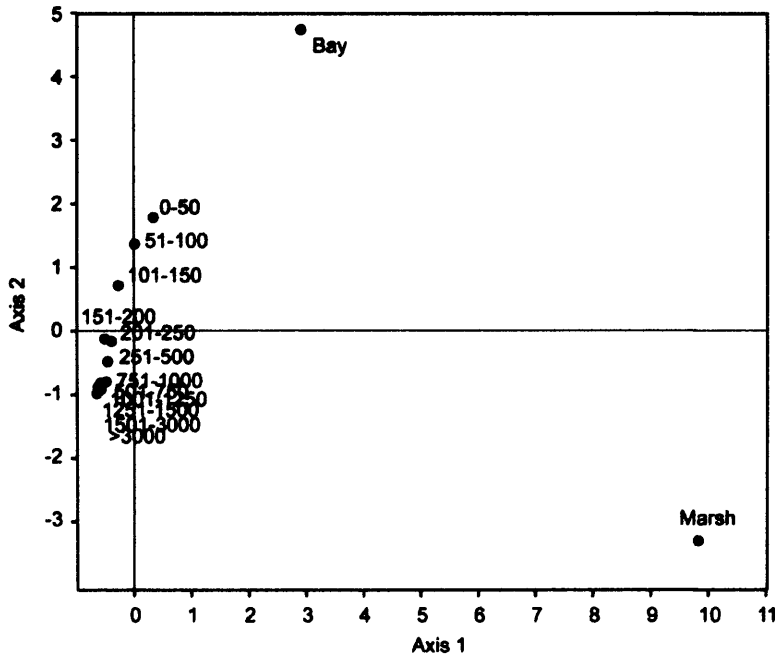


Figure 4.10 Results of CA for the data set of Culver (1988) (redrawn from Hammer & Harper 2006). The depths at which benthic foraminifera were collected are arranged along the first axis, which is the principal ecological gradient.

CHAPTER 5 – RESULTS WELL PLUTAO-1

5.1 Biostratigraphy and Age / Depth Model

Well Plutao-1 (2750 – 4280 m) spans the Upper Oligocene to Middle Miocene (fig. 5.4), based on planktonic foraminiferal, calcareous nannofossil, and oxygen isotopic stratigraphical events. The Miocene section (2750 – 3470 m) contains sporadic calcareous foraminifera allowing the biostratigraphy to be relatively well defined with planktonic foraminiferal and oxygen isotopic data. The Upper Oligocene section (3480 – 4280 m) is almost entirely agglutinated in nature, and so biostratigraphy is much less-well resolved and largely based on calcareous nannofossil data (obtained from Keith Knabe, ExxonMobil) as well as an analysis of the agglutinated benthic foraminifera.

As the majority of samples are ditch cuttings there is always a possibility that stratigraphically younger index fossils can appear in some samples, which is due to the problem of down-hole caving (parts of the hole sides becoming detached whilst drilling older strata). This phenomenon is rare and not commonly observed in the wells in this study, partly due to the capabilities of the advanced drilling-mud used for these wells (R. Jones, personal communication). Because of caving, the use of the oldest stratigraphic signal in a given sample is commonly given precedence when working with ditch cuttings, but in the Congo Fan reworking of older fossils is also a significant potential problem.

5.1.1 Miocene

The age model for the Miocene of well Plutao-1 (fig. 5.1) has been constructed using planktonic foraminiferal events, and an additional oxygen isotope event (Mi2), with a linear sedimentation rate inferred between tie-points. All events are fitted to the Lourens et al. (2004) timescale. The age ranges used for all planktonic foraminifera found in this study are given in figure 5.2, based on the works of Ogg and Lugowski (2007), Berggren et al. (1995), Bolli and Saunders (1985) and Kennett and Srinivasan (1983), and a brief discussion of each species is presented in the taxonomic part of this thesis (Chapter 14). As the recovery of planktonic foraminifera was relatively low (see fig. 5.4), first and last occurrences are not a useful indication of age and so in most cases we have used these only as a guide.

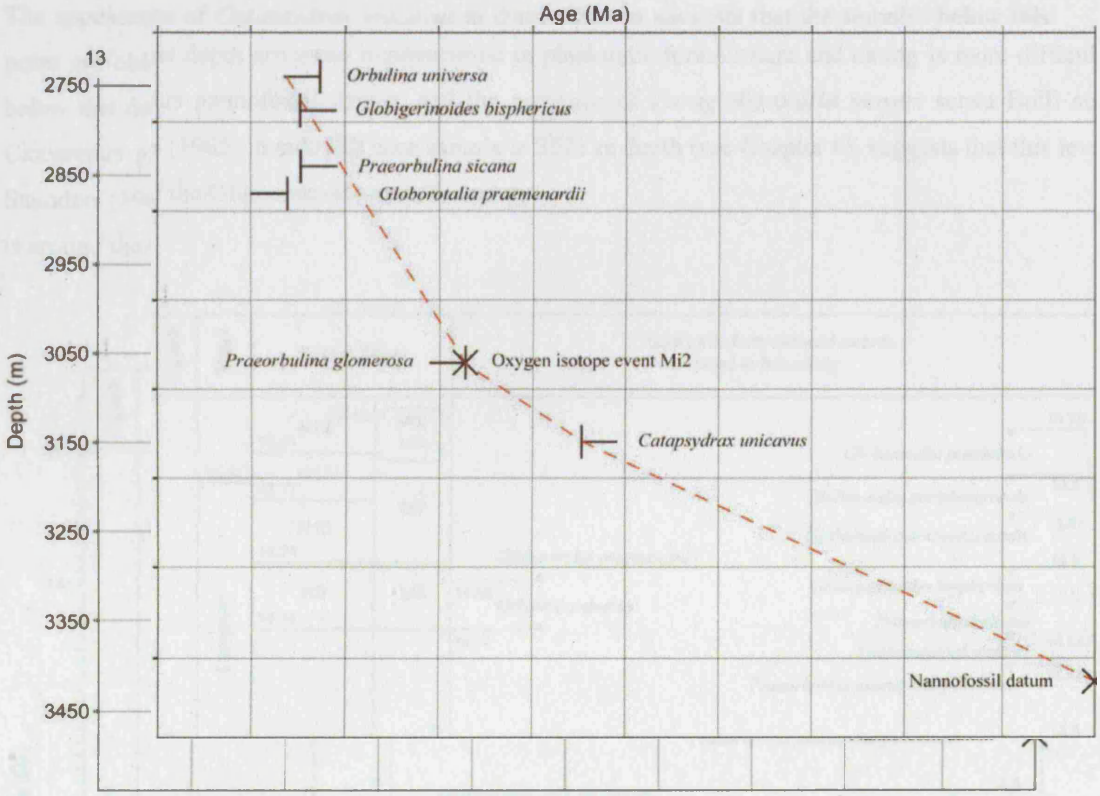


Figure 5.1 Age / depth model for the Miocene section of Plutao-1, including important biostratigraphical events used for its construction. Linear sedimentation rate is assumed between points.

The upper section of the well (2760 – 2890 m) is constrained to Middle Miocene (Langhian) by the occurrence of *Orbulina universa*, *Globigerinoides bisphericus* and *Praeorbulina sicana*, whose ranges overlap in this interval. The occurrence of *Globorotalia praemenardii* at 2930 m suggests an earlier age but may be caved as the older form *G. bisphericus* occurs significantly higher in the section.

The occurrence of *Praeorbulina glomerosa glomerosa* at 3120 m suggests an age of no older than about 16.3 Ma (Berggren et al. 1995), and this depth also coincides with oxygen isotope event Mi2 (Miller et al. 1991) at 16.1 Ma seen in the isotope record from this study (fig. 5.3) as the beginning of global cooling ($\delta^{18}O$ increase). The $\delta^{13}C$ record also fits the global trend at this location.

The appearance of *Catapsydrax unicavus* at depth 3210 m suggests that the samples below this point are older than the top of zone N6 (Kennett and Srinivasan 1983) at 17.5 Ma. Samples below this depth are more impoverished in planktonic foraminifera and dating is more difficult. Calcareous nannofossil dating, and the presence of *Paragloborotalia mayeri* sensu Bolli and Saunders (1985) in sidewall core sample at 3521 m depth (see Chapter 6), suggests that this level is around the Oligocene-Miocene boundary.

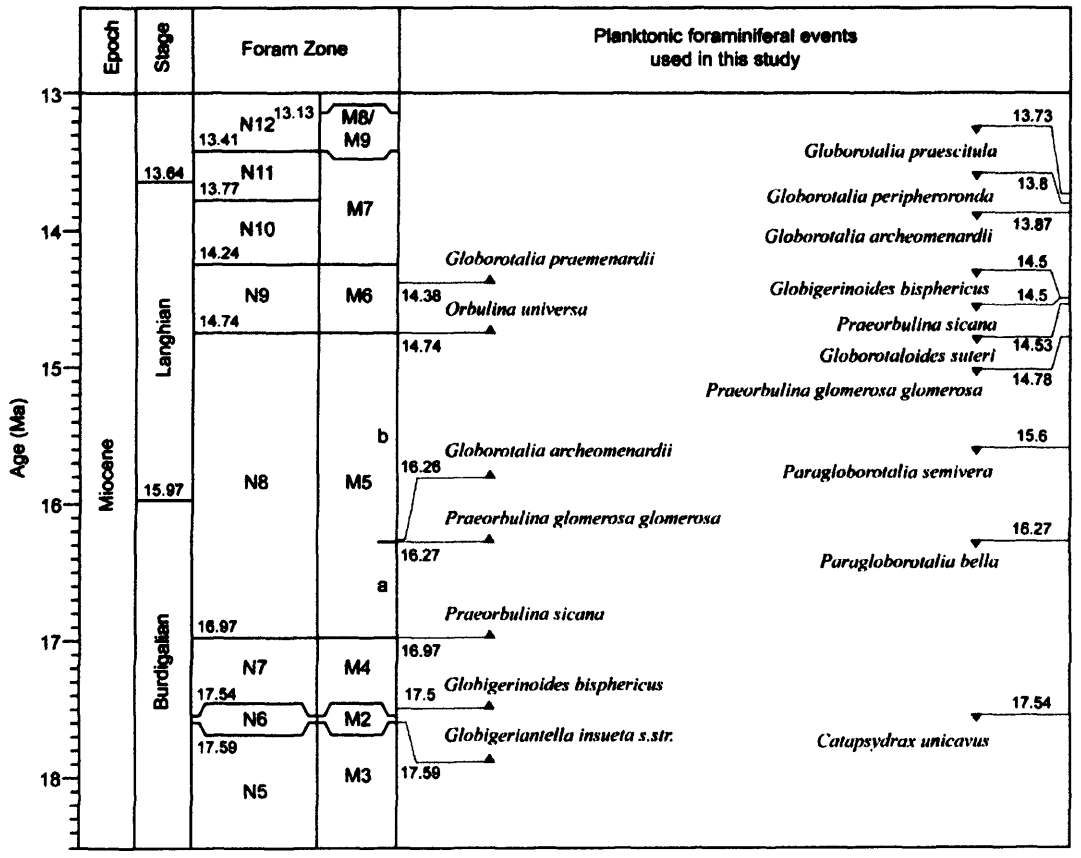


Figure 5.2 Absolute ages for planktonic foraminifera encountered in this study against the timescale of Gradstein et al. (2004). Events compiled from Ogg and Lugowski (2007); Berggren et al. (1995); Bolli and Saunders (1995); and Kennett and Srinivasan (1983).

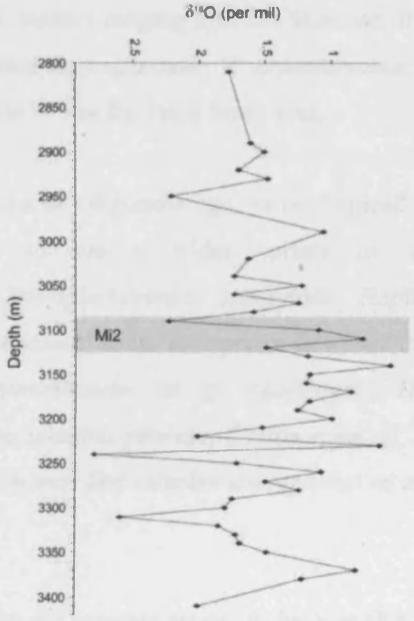


Figure 5.3 Oxygen isotope results for Plutao-1. The oxygen isotope event Mi2 (Miller at al. 1991) is given (shaded area).

5.1.2 Oligocene

Biostratigraphy for the Oligocene section of Plutao-1 has been carried out using calcareous nannofossils (obtained from Keith Knabe, ExxonMobil), which constrain the age of the samples to the Upper Oligocene.

Agglutinated foraminifera (see figs 5.9, 5.10 and Appendix 2) also indicate an Oligocene age when compared with biostratigraphic studies from the Norwegian-Greenland and North Seas. Verdenius & Hinte (1983) recorded *H. walteri*, *B. multicamerata* and *R. acutidorsatum* as terminating at the end of the Oligocene in the Norwegian-Greenland Sea, all of which are present in the studied samples. However, Verdenius & Hinte (1983) also record *R. amplectens* and *K. conversa* as terminating at the end of the Eocene, which are also present in the samples, suggesting possibly a longer stratigraphic range in the Equatorial Atlantic for these species. Gradstein *et al.* (1994) recorded similar last occurrences in the North Sea, whilst Charnock & Jones (1990, 1997) recorded *R. amplectens* ranging to the end of the Oligocene in the Central North Sea. They also listed *L. lituiformis* and *H. globulifera* as terminating at the end Oligocene,

with *R. acutidorsatum* and *H. walteri* ranging into the Miocene. It is perhaps worth noting that Kaminski et al. (2005) recorded *R. amplectens, R. acutidorsatum* and *H. walteri* ranging well into the Middle Miocene at Site 909 in the Fram Strait area.

The samples are regarded to be of Oligocene age, as no 'typical' Eocene fauna is observed in which one would expect to see a wider variety of *Trochamminoides* spp. and *Paratrochamminoides* spp., *Spiroplectammina spectabilis*, *Haplophragmoides stomatus* and higher abundances of *A. peruvianus*. There are species however that are not recorded from the Eocene, such as *Paratrochamminoides* ex gr. *challengeri*, *Haplophragmoides carinatus*, *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana*. The samples are regarded as unlikely to be of Miocene age due to persisting *H. walteri*.

Specimens of *R. amplectens* in our samples appear to have evolved a more acute periphery and larger size than the typical Eocene forms (Plate 41, fig. 11). There are also at least two other forms in the samples similar in appearance to *R. amplectens* but perhaps deriving from a different lineage (possibly *R. acutidorsatum*). *Reticulophragmium amplectens* ssp. 1 (Plate 41, fig. 12; Plate 44, figs 7,8) exhibits elongated alveoles, but has a larger size and less acute periphery. The *R. amplectens / acutidorsatum* transitional form (Plate 44, figs 9,10) shows an acute periphery in accordance with *R. amplectens*, but has a larger size and is transitional between round and elongate alveoles. There is no reference to specimens with these characteristics from other regions, and so it is presumed that the evolution of these forms carried on into the Oligocene in the low latitude South Atlantic.

5.2 Benthic Foraminiferal Assemblages

Fourteen assemblages have been defined for Plutao-1 based on faunal changes, with the aid of Correspondence Analysis and morphogroup analysis (figs 5.4 – 5.10). These are, from youngest to oldest:

(1) Low abundance agglutinated Assemblage 1 (2750 – 2800 m) consists of low abundance faunas (less than 50 specimens per 100 g), largely agglutinated in nature, and with low diversity (less than 7 species per sample, Fisher's $\alpha x \leq 4$). Common species are *Glomospira gordialis*, *Rhabdammina* spp. and *Bathysiphon* spp. Sand percentage is relatively high (around 5 %).

(2) *Glomospira* Assemblage 2 (2810 – 2880 m) consists of medium diversity faunas (around 20 to 40 species per sample, Fisher's $\alpha x = 10$) of almost entirely agglutinated foraminifera. Absolute abundance is low (around 200 specimens per 100 g). The most commonly occurring species are *Glomospira gordialis*, *Bathysiphon* spp., *Rhizammina* spp., *Rhabdammina cylindrica* and *Saccammina* cf. *sphaerica*. Sand percentage is low.

(3) *Valvulineria pseudotumeyensis* Assemblage 3 (2890 – 2920 m) consists of low diversity faunas (around 20 species per sample, Fisher's $\alpha x = 8$) with high relative abundance (up to 2272 specimens per 100 g), and is dominated by the species *Valvulineria pseudotumeyensis*. The assemblage is largely calcareous in nature. *Bulimina falconensis* and *Brizalina alazanensis* are also common. Sand content is relatively low (maximum 5 %).

(4) Low diversity *Bulimina* Assemblage 4 (2930 – 3020 m) consists of a largely calcareous fauna with low diversity (around 20 species per sample, Fisher's $\alpha x = 8$) and wildly fluctuating absolute abundance (from 100 to 6800 specimens per 100 g). The most commonly occurring species are *Bulimina elongata*, *Brizalina* cf. *barbata*, *Uvigerina* aff. *carapitana*, *Brizalina alazanensis* and *Bulimina marginata*. Sand content is relatively low (maximum 5 %).

(5) Agglutinated Assemblage 5 (3030 – 3040 m) consists of high diversity faunas (around 40 species per sample, Fisher's $\alpha x = 15$) of almost entirely agglutinated foraminifera. Absolute abundance is high (around 500 specimens per 100 g). The most commonly occurring species are *Glomospira gordialis*, *Paratrochamminoides* spp., *Cyclammina* spp., *Reticulophragmium* spp., *Bathysiphon* spp. Sand percentage is low.

(6) High diversity *Cibicidoides* Assemblage 6 (3050 – 3230 m) consists of high diversity faunas (around 50 species per sample, Fisher's $\alpha x = 20$) of both agglutinated and calcareous foraminifera, and higher abundances (20 to 40 specimens per sample) of planktonic foraminifera. Absolute abundances are also high (200 to 700 specimens per 100 g). The most commonly occurring species are *Cibicidoides crebbsi*, *Oridorsalis umbonatus*, *Hanzawaia mantaensis*, *Uvigerina mantaensis*, *Bolivina tenuisstriata*, *Haplophragmoides* cf. *bradyi* and *Paratrochamminoides* spp. Sand percentage is low.

(7) Low diversity agglutinated Assemblage 7 (3240 – 3410 m) is characterised by almost exclusively agglutinated foraminifera and low diversity faunas (around 20 species per sample, Fisher's $\alpha x = 10$). Absolute abundance is also low. The most commonly occurring species in this

assemblage are *Rhabdammina cylindrica*, *Nothia excelsa*, *Nothia* spp., *Rhizammina* spp., *Glomospira gordialis*, *Glomospira irregularis*, *Haplophragmoides* cf. *bradyi*, *Saccammina sphaerica* and *Reticulophragmium* spp. This assemblage also contains a slightly higher proportion of sand (around 5 %).

(8) 'Barren' channel Assemblage 8 (3420 – 3620 m) is characterised by barren samples containing fine to coarse grained sand of varying proportions (20 – 60 %). Although these ditch cutting samples are barren, sidewall cores over the same interval reveal a diverse fauna (see Chapter 6).

(9) Low abundance agglutinated Assemblage 9 (3630 – 3720 m) consists of low diversity and low abundance faunas (typically 7 specimens per sample, Fisher's $\alpha x \leq 5$), and a higher sand content than the assemblages below (around 20 %). The most persistently occurring species are *Nothia robusta* and *Ammodiscus latus*, with occasional *Rhabdammina* spp., *Rhizammina* spp., *Glomospira charoides*, *Reticulophragmium rotundidorsatum* and *Recurvoides* spp.

(10) *Textularia earlandi* Assemblage 10 (3730 – 3780 m) consists of five samples showing low diversity and abundance (typically less than 100 specimens, and less than 20 species per sample, Fisher's $\alpha x = 5$ to 10). *Nothia latissima* is by far the most persistently occurring form, with over 40 fragments at some horizons. *Textularia earlandi* and *Ammodiscus latus* are also persistent, although not abundant, whilst other species occur rarely such as *Glomospira charoides*, *Nothia robusta*, *Saccammina* spp., *Hormosina globulifera*, *Trochammina* spp., *Portatrochammina profunda*, *Ammosphaeroidina* spp., *Subreophax scalaris*, *Ammolagena* spp. and *Haplophragmoides* spp. Sand content is variable and high in some samples.

(11) *Portatrochammina profunda* Assemblage 11 (3790 – 3860 m) is characterised by persistently occurring *Portatrochammina profunda*, which reaches a maximum of 31 specimens per 100 g in this interval. Overall diversity is high (Fisher's $\alpha x = 15$), but is lower in the upper section as sand content begins to increase. The sediments in many of the samples exhibit a dark colouration. Other persistent forms include *Rhabdammina* spp., *Ammodiscus latus*, *Nothia robusta*, *Rhizammina* spp., *Hormosina globulifera*, *Nothia latissima*, *Ammosphaeroidina* sp. 1, *Haplophragmoides nauticus*, *Nothia* aff. *excelsa* and *Psammosphaera* cf. *fusca*. In general the tubular forms are at their least dominant over the entire studied interval, at around 45 % of the assemblage.

(12) High diversity *Reticulophragmium* Assemblage 12 (3870 – 3990 m) consists of agglutinated faunas where diversity increases gently up to a maximum of around 40 species per sample (Fisher's αx = 20). Abundance is lower than in the section below (typically around 130 specimens per sample), whilst sand content is variable but generally low. Tubular forms of *Rhabdammina* spp., *Rhizammina* spp., *Nothia robusta*, *Bathysiphon* spp. and *Nothia* aff. *excelsa* dominate over 50% of the assemblage. Persistent species include *Reticulophragmium acutidorsatum*, *Reticulophragmium rotundidorsatum*, *Ammodiscus latus*, *Haplophragmoides* spp., *Portatrochammina profunda* and *Discamminoides* sp. 1.

(13) *Scherochorella congoensis* Assemblage 13 (4000 – 4100 m) is marked by a lowering of diversity (Fisher's αx = 5 to 10) and an increase in abundance. This is due to the significant domination of the species *Nothia robusta* (up to 233 fragments per sample), *Scherochorella congoensis* (up to 300 fragments per sample) and *Discamminoides* sp. 1. Other diagnostic forms include *Reticulophragmium rotundidorsatum*, *Reticulophragmium amplectens*, *Saccammina spherica*, *Trochammina* spp., *Ammodiscus latus*, *Reophax pilulifer*, *Rhizammina* spp. and *Rhabdammina* spp. Sand content is generally low, with many samples showing a dark colouration.

(14) *Nothia robusta / Reticulophragmium* Assemblage 14 (4110 – 4270 m) is the lowermost interval in the section and contains a fauna decreasing in diversity (Fisher's αx = 10) and abundance from around 300 down to 50 specimens per sample. The bottom of the section is marked by some sandy levels and the occurrence of dark coloured shales up to 4190 m. The most persistent and abundant species are *Nothia robusta*, *Reticulophragmium rotundidorsatum* and *Reticulophragmium acutidorsatum*. Other persistent species are *Discamminoides* sp. 1, *Rhabdammina* spp., *Bathysiphon* spp., *Reophax pilulifer*, *Recurvoides* spp., *Reticulophragmium amplectens* and calcareous forms of *Valvulineria* spp. This assemblage contains a variety of other agglutinated specimens, with the tubular forms increasing in dominance from around 50% at the top of the assemblage to 70% near the base.

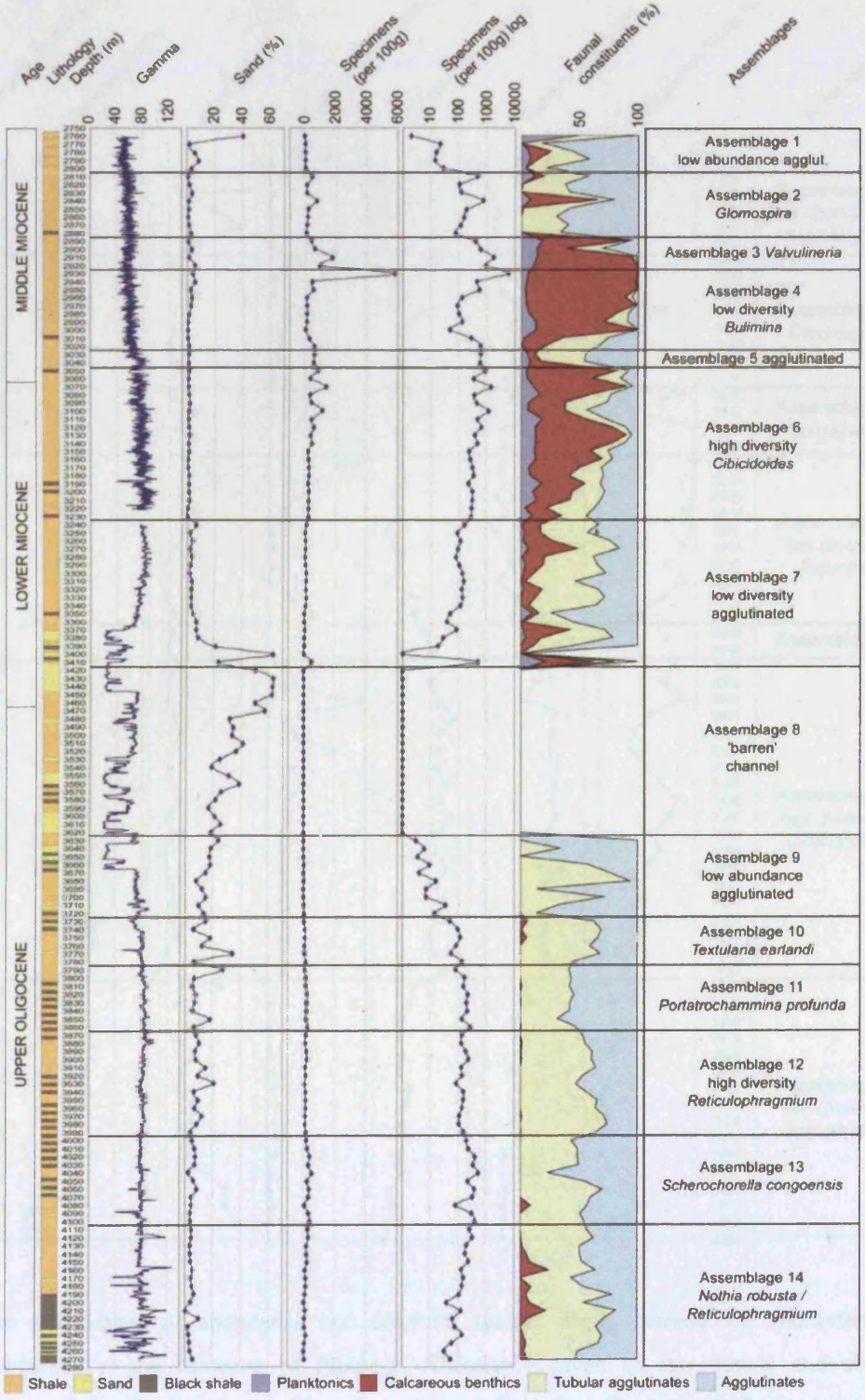


Figure 5.4 Summary of Plutao-1 Assemblages 1 – 14 against depth, lithology and abundance.

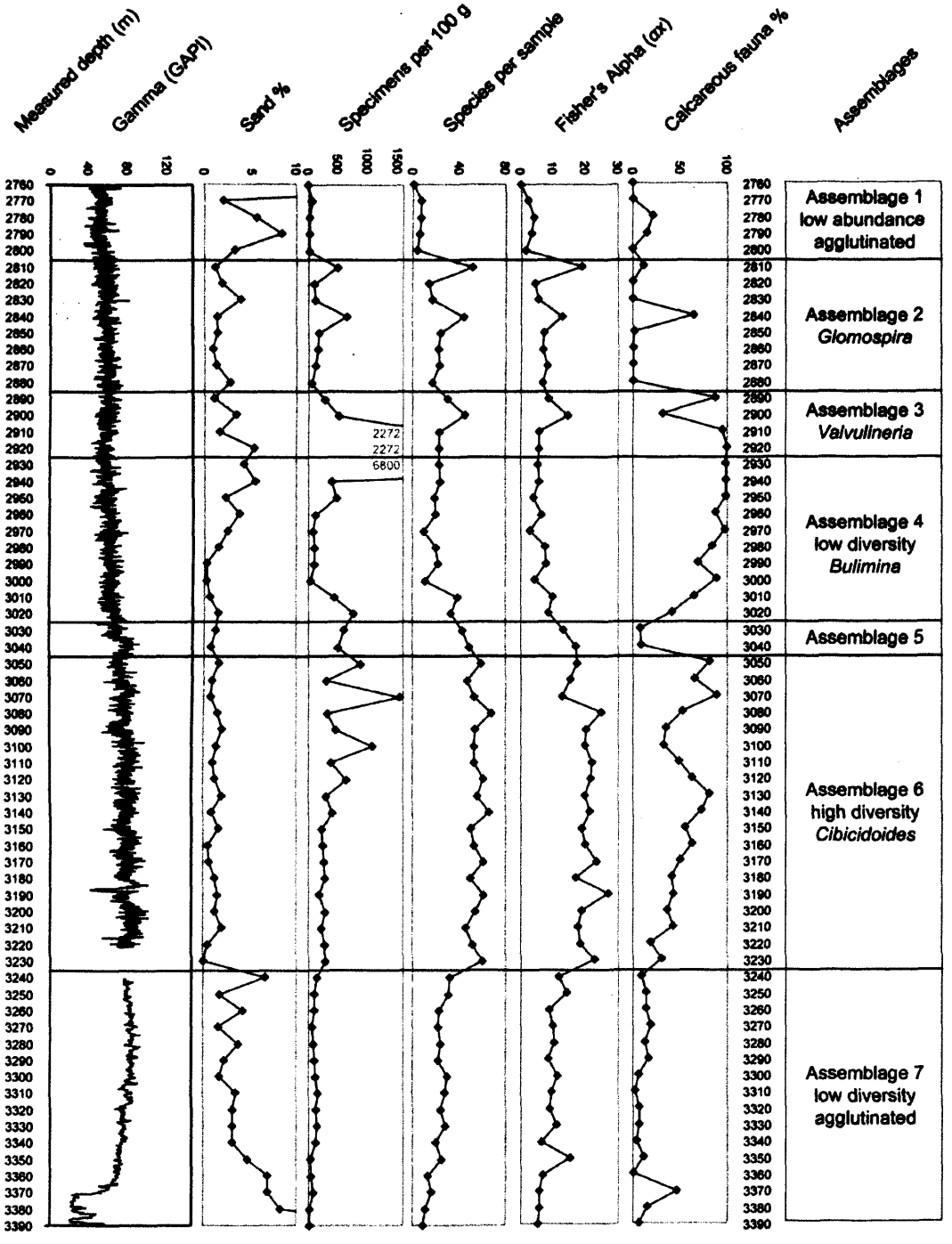


Figure 5.5 Graphs of abundance and diversity against depth, gamma log and interpreted assemblages for the Miocene of Plutao-1. Abundance given as raw counts and absolute abundance, diversity given as number of species and Fisher's α. Percentage of calcareous fauna is also shown.

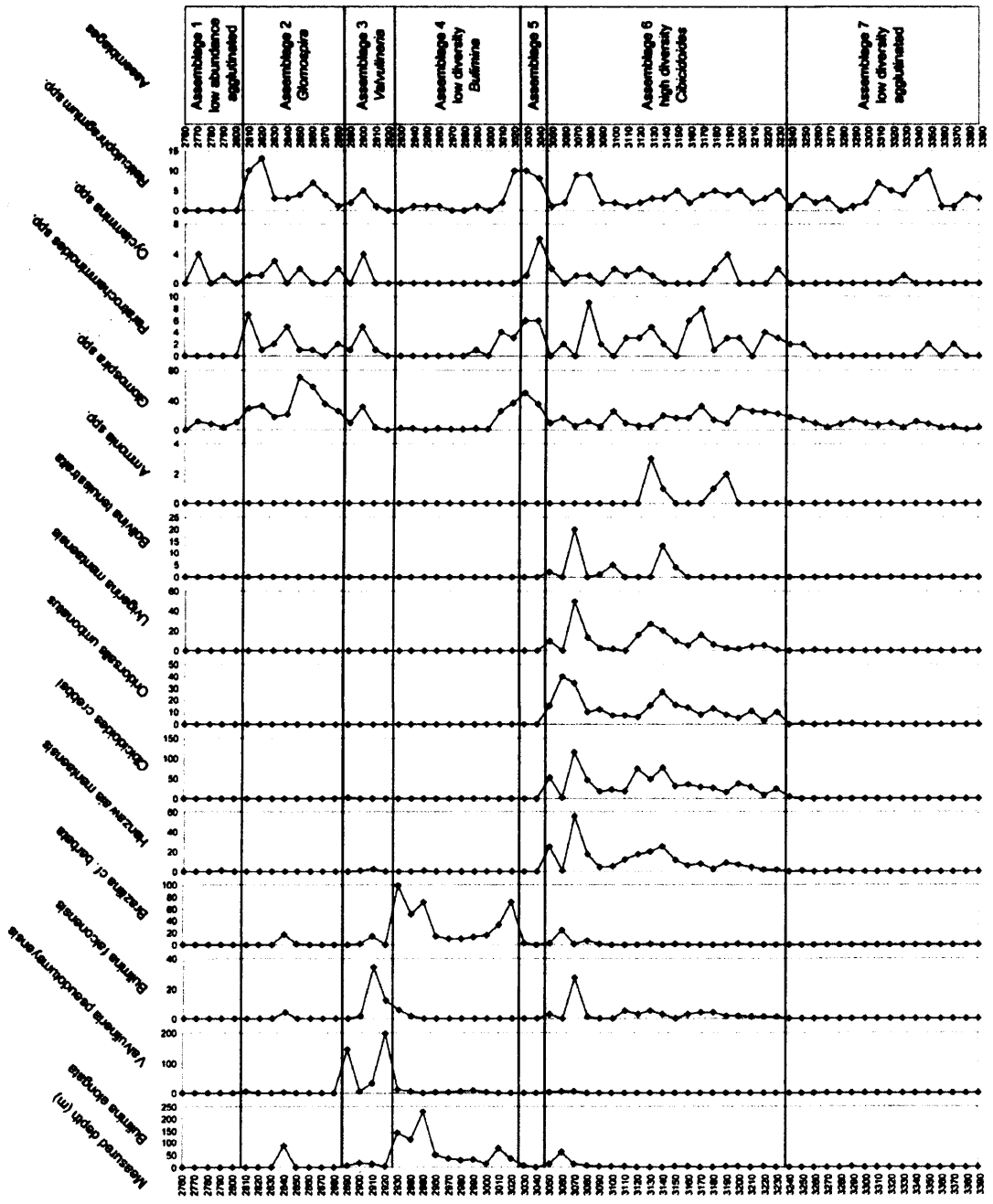


Figure 5.6 Graphs of selected species abundances against depth and interpreted assemblages for the Miocene of Plutao-1. Data represents raw species counts.

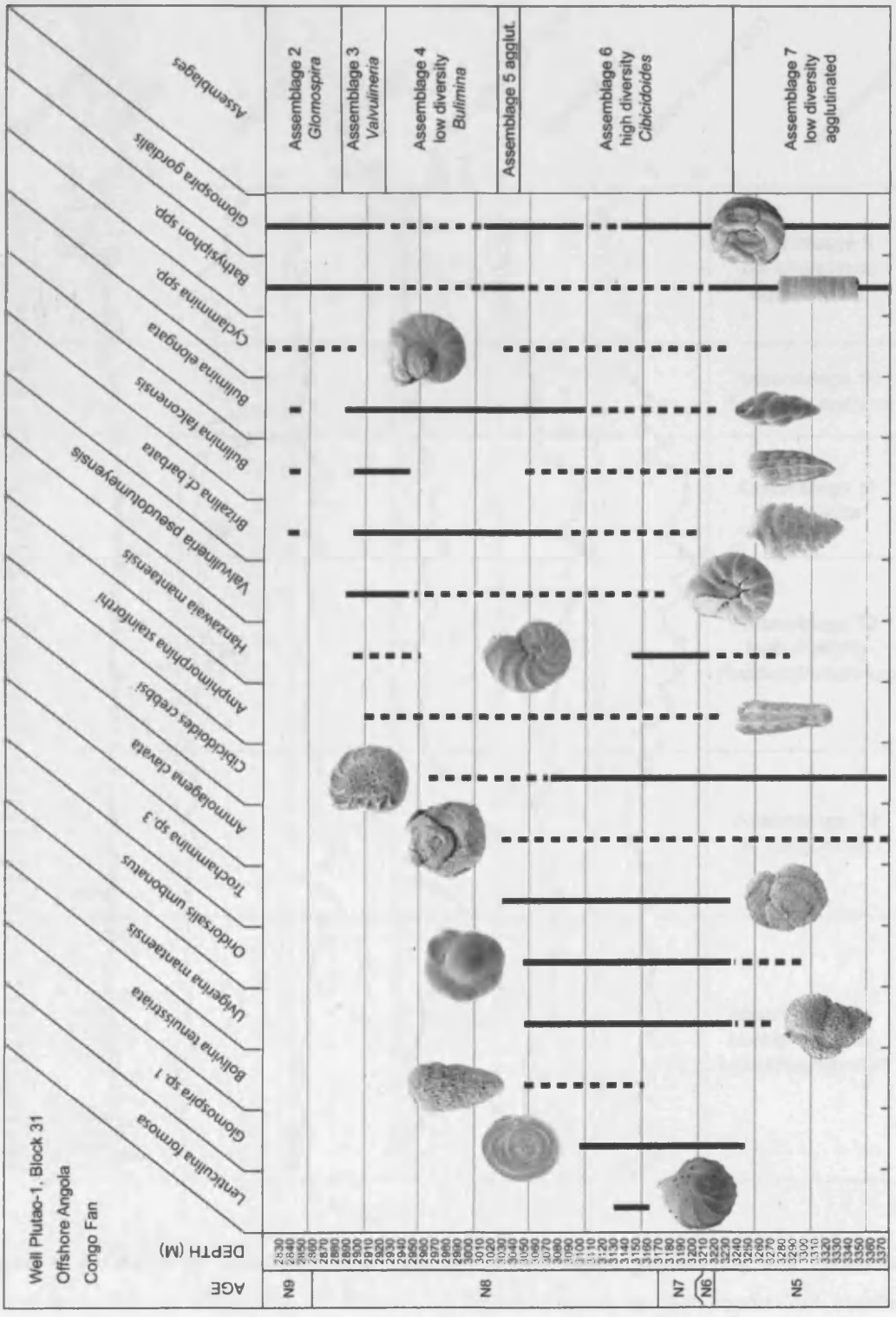


Figure 5.7 Ranges of selected commonly occurring foraminifera against depth and assemblages for the Miocene section of Plutao-1. Dashed lines indicate sporadic occurrence.

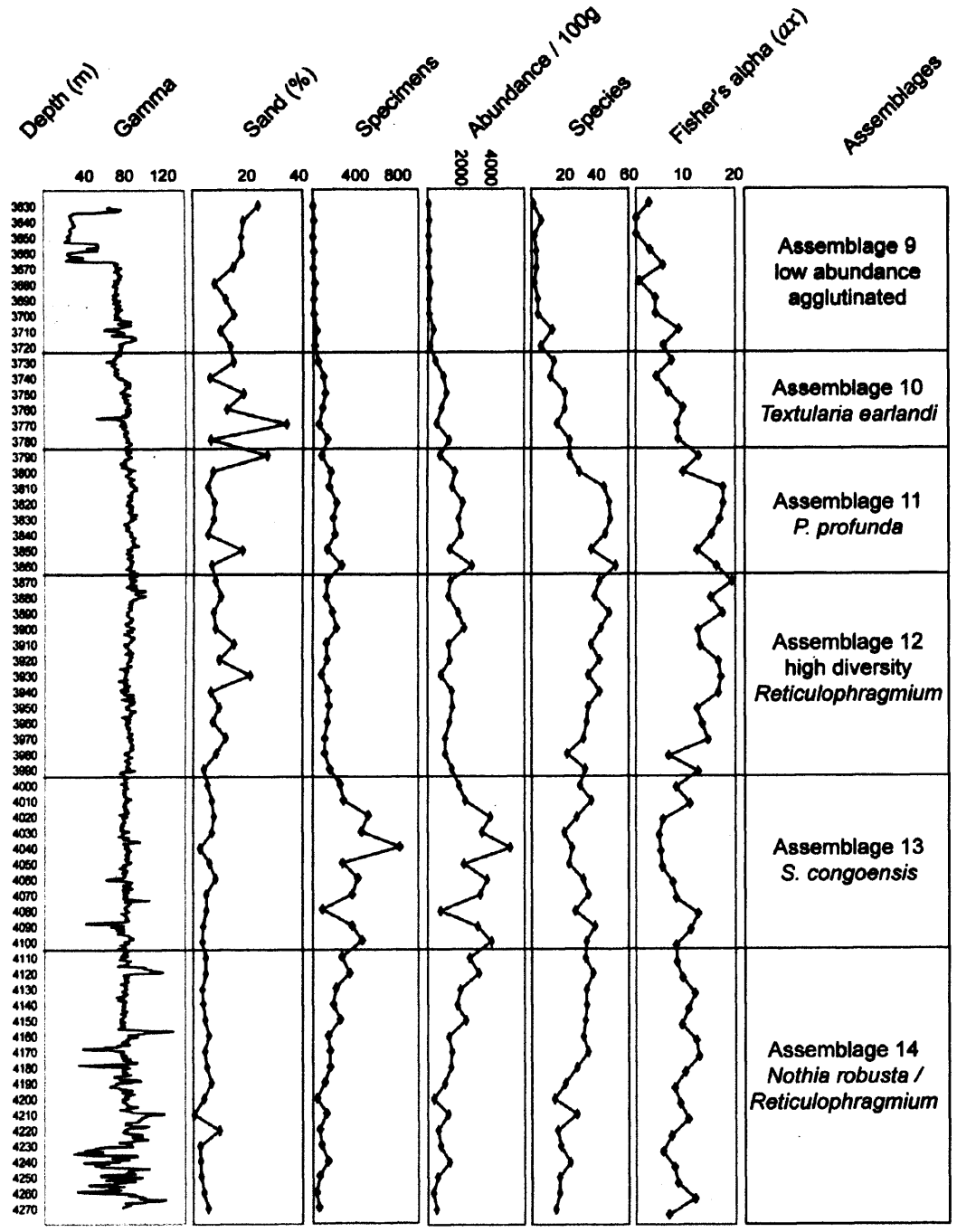


Figure 5.8 Graphs of abundance and diversity against depth, gamma log and interpreted assemblages for the Oligocene of Plutao-1. Abundance given as raw counts and absolute abundance, diversity given as number of species and Fisher's α. Percentage of sand content by weight is also shown.

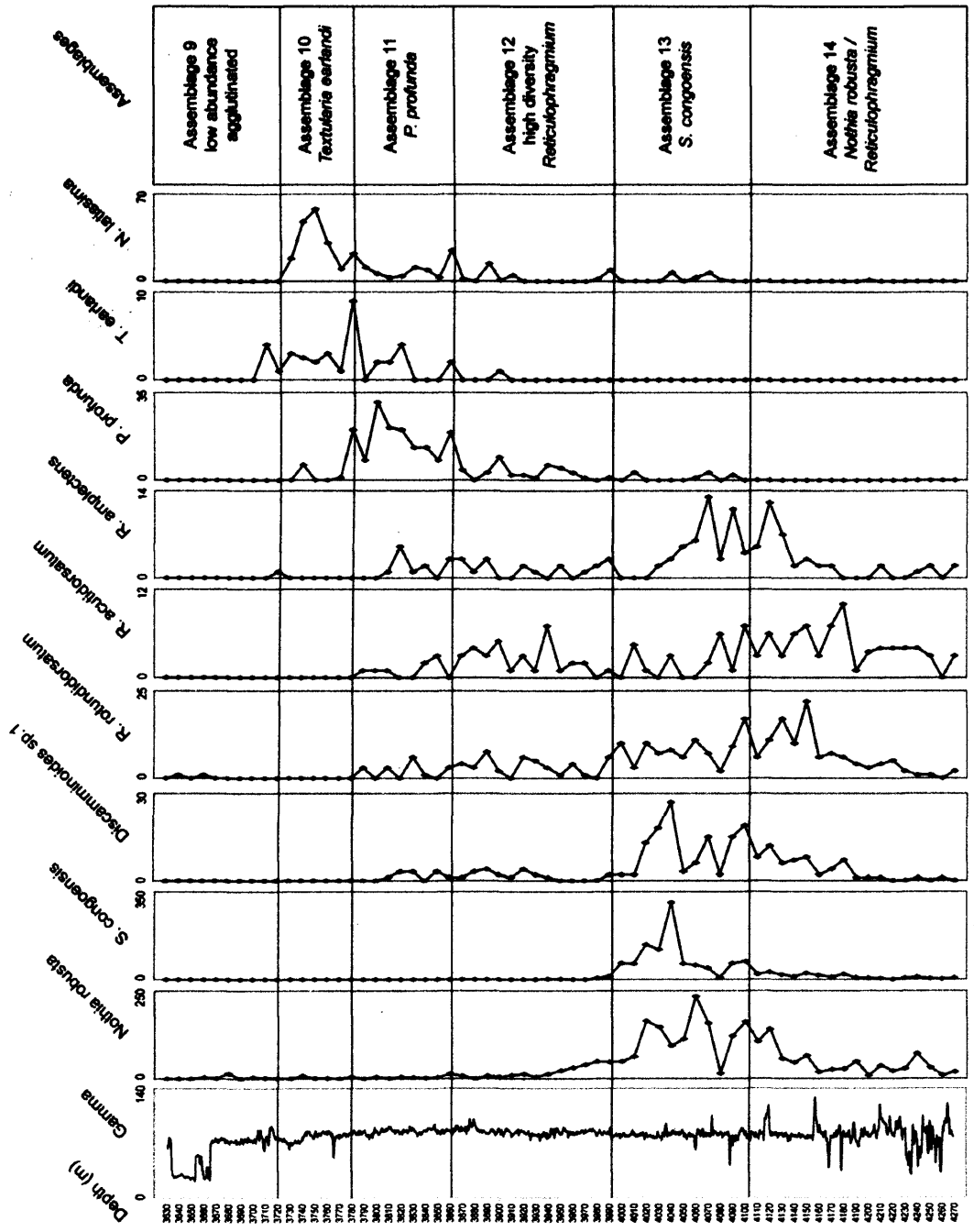


Figure 5.9 Graphs of selected species abundances against depth and interpreted assemblages for the Oligocene of Plutao-1. Data represents raw species counts.

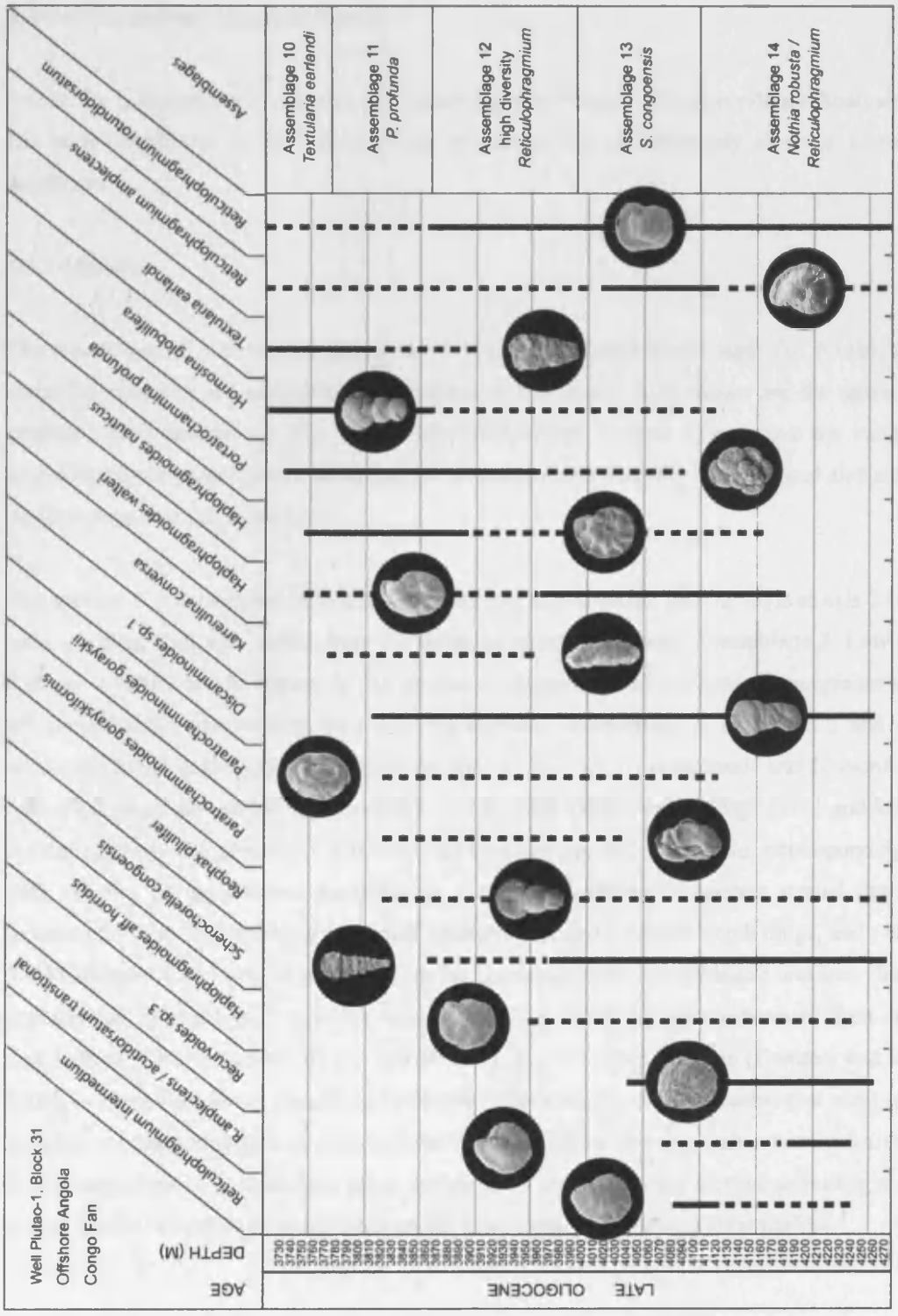


Figure 5.10 Ranges of selected commonly occurring foraminifera against depth and assemblages for the Oligocene section of Plutao-1. Dashed lines indicate sporadic occurrence.

5.3 Correspondence Analysis Results

Due to the high number of samples and assemblages in Plutao-1, Correspondence Analysis (CA) has been carried out on the Miocene and Oligocene sections separately in order to enhance resolution.

5.3.1 Miocene

The results from CA reveal the clustering of samples from each assemblage (fig. 5.11b), adding statistical evidence for assemblages designated in this study. Also shown are the species that dominate each assemblage (fig. 5.11a). This independent analysis helps prove the validity of assemblages designated above using species abundance and diversity changes, and also supports morphogroup results (see below).

The species *V. pseudotumeyensis* (fig. 5.11) has low axis 1 values and the highest axis 2 values, corresponding well with depths from *Valvulineria pseudotumeyensis* Assemblage 3. Low axis 1 and axis 2 values are dominated by the species *B. elongata*, *B.* cf. *barbata*, *B. marginata* and *U.* aff. *carapitana*, corresponding well with the *Bulimina* Assemblage 4. High axis 1 and axis 2 values are found in the species *Cibicidoides* spp., *C. crebbsi*, *H. mantaensis* and *U. mantaensis*, with good correlation to the High diversity *Cibicidoides* Assemblage 6. High axis 1 and low axis 2 values contain the species *G. gordialis*, *Bathysiphon* sp. and *N. excelsa*, corresponding well with samples of agglutinated Assemblages 1 and 5. Clustering of species around the origin indicates those species showing no overall clustering around a narrow depth range, and / or very low abundance. Clustering of samples from the Low abundance Assemblage 1 and Low diversity agglutinated Assemblage 7 near the origin indicates a similarity on the basis of their species distributions. Clustering towards one end of axis 1, known as compression (Hammer and Harper 2006), is expected and not thought to be obviously meaningful. It is noticeable that most species showing constrained ranges about particular depths (high or low axis values) are calcareous in nature. Agglutinated foraminifera, taken separately, vary little up the section, providing a more-or-less 'single' assemblage overprinted on the more variable calcareous foraminifera.

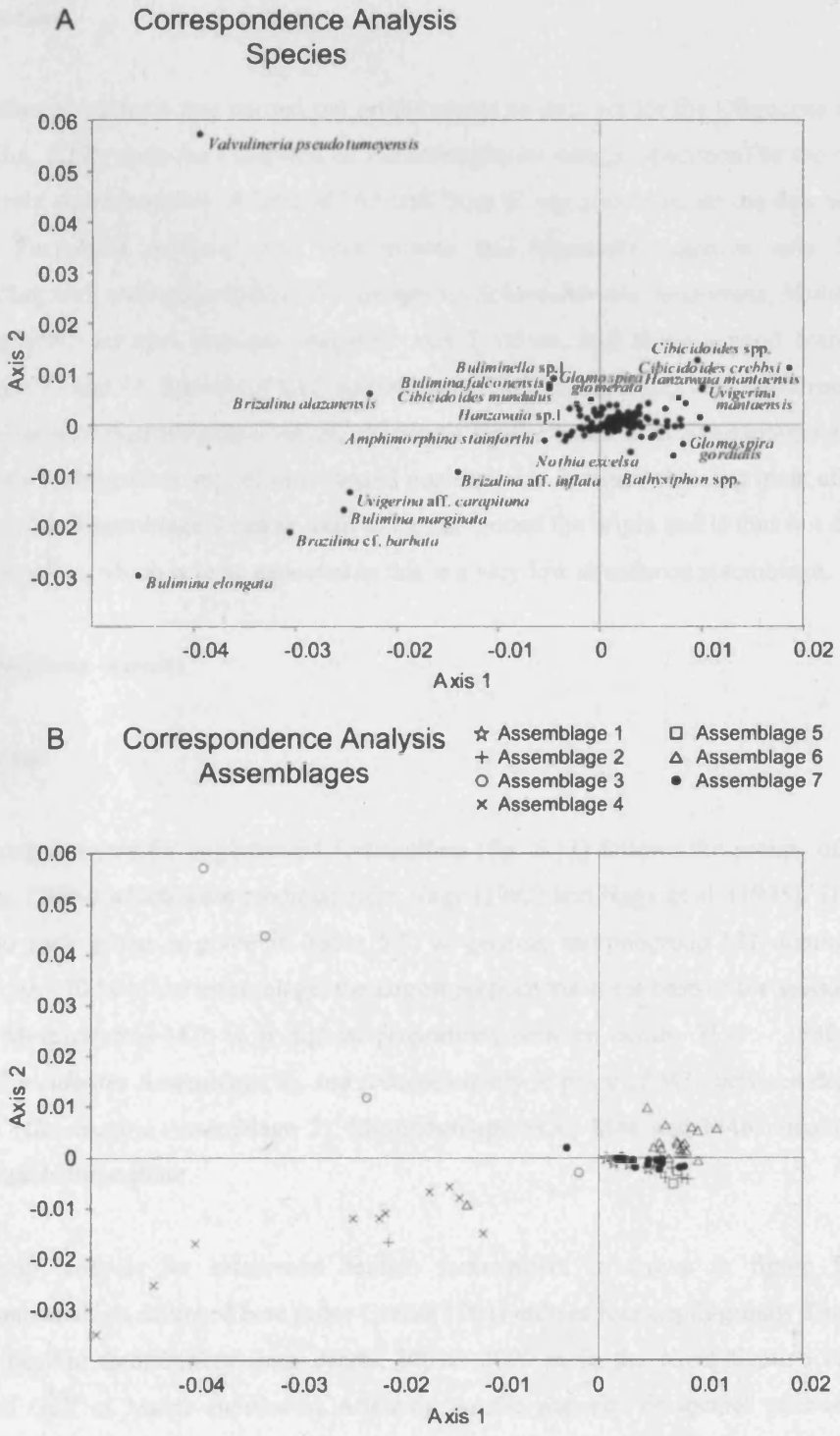


Figure 5.11 Results of Correspondence Analysis for the Miocene of Plutao-1, including **A** all species, and **B** all samples. Sample depths have been converted to symbols referring to assemblage affinity.

5.3.2 Oligocene

Correspondence Analysis was carried out on the complete data set for the Oligocene section of Plutao-1 (fig. 5.12), with the exception of *Valvulina flexilis* (single specimen) as the data point meaninglessly skewed results. A total of 163 taxa from 63 samples made up the data set. *Nothia latissima*, *Textularia earlandi* and *Saccammina* sp.1 dominate negative axis 2 values, corresponding well with Assemblage 10. The species *Scherochorella congoensis*, *Nothia robusta* and *Discamminoides* sp.1 dominate negative axis 1 values, and show a good correlation to Assemblages 13 and 14. Species of *Rhizammina* spp., *Rhabdammina* spp. and *Portatrochammina profunda* dominate positive axis 1 values, showing a similar location to Assemblages 11 and 12, whilst *Reticulophragmium* spp. cluster around positive axis 2 values showing most affinities to Assemblage 14. Assemblage 9 can be seen to cluster around the origin and is thus not defined by any of the species, which is to be expected as this is a very low abundance assemblage.

5.4 Morphogroup Results

5.4.1 Miocene

Morphogroup analysis for agglutinated foraminifera (fig. 5.13) follows the groups of Van den Akker et al. (2000) which were modified from Nagy (1992) and Nagy et al. (1995). The species assigned to each group is given in Table 5.2. In general, morphogroup M1 dominates with frequently 50 – 70 % of the assemblage, the largest proportions at the base of the section (3390 – 3240 m). Morphogroup M2b is at highest proportions between depths 3170 – 3030 m (High diversity *Cibicidoides* Assemblage 6), and reduces rapidly in place of M3a between depths 2880 – 2780 m (*Glomospira* Assemblage 2). Morphogroups M2c, M4a and M4b remain low and relatively stable throughout.

Morphogroup analysis for calcareous benthic foraminifera is shown in figure 5.13. The morphogroup analysis followed here (after Corliss 1991) utilises four depth-groups distinguished from live benthic foraminifera from depths 200 to 3000 m in the Nova Scotian continental margin and Gulf of Maine (northwest Atlantic). As the majority of species encountered are different from those used by Corliss (1991), species have been assigned to groups based on their morphological similarities to those forms (Table 5.1).

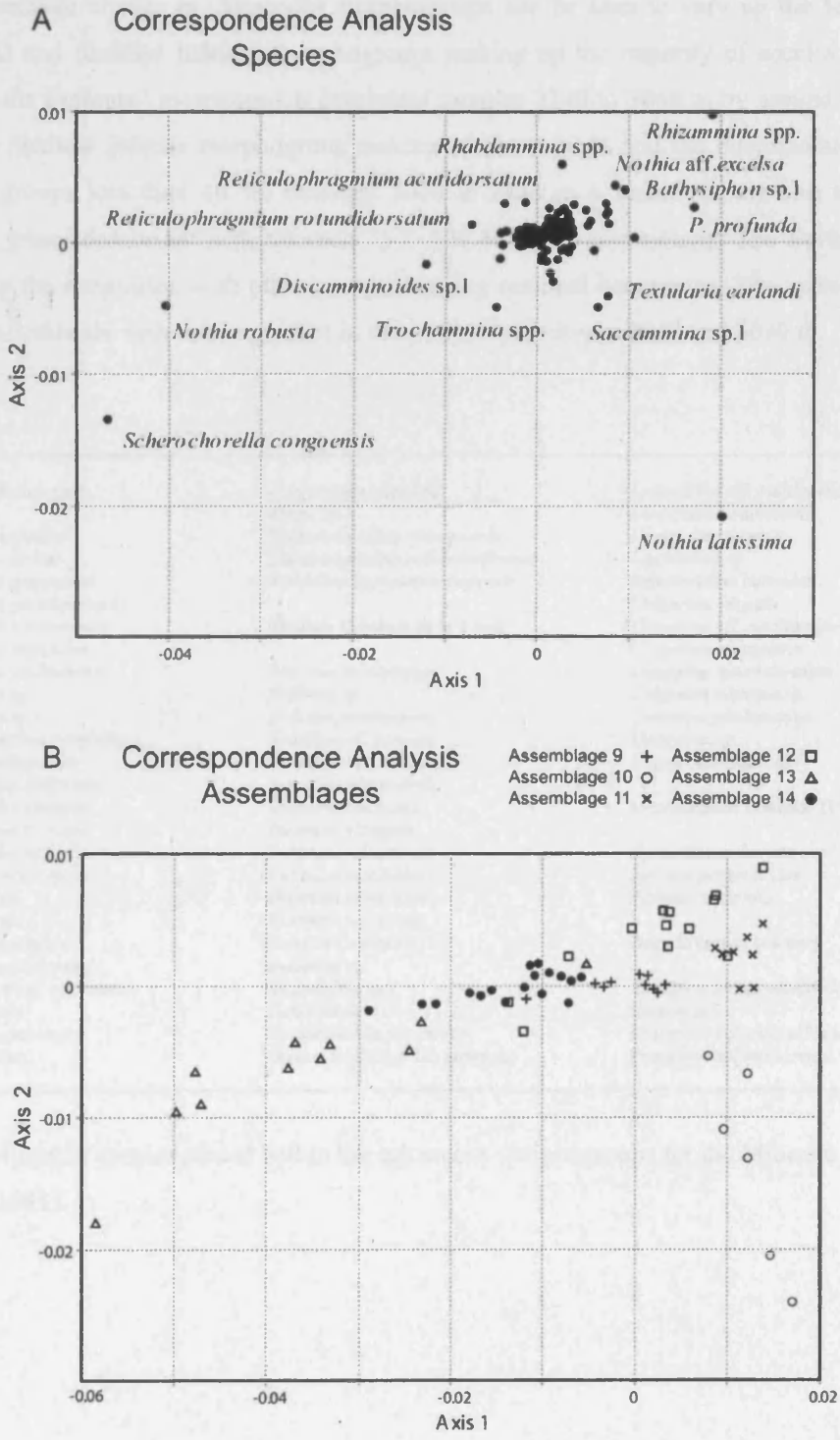


Figure 5.12 Results of Correspondence Analysis for the Oligocene of Plutao-1, including **A** all species, and **B** all samples. Sample depths have been converted to symbols referring to assemblage affinity.

The percentage change in calcareous morphogroups can be seen to vary up the section, with Epifaunal and Shallow Infaunal morphogroups making up the majority of species present. In general, the Epifaunal morphogroup dominates samples 3390 to 3040 m by around 60 – 70 %, with the Shallow Infauna morphogroup making up about 30 % and the Intermediate and Deep Infauna groups less than 10 %. Between 3030 to 2840 m a switch occurs and the Shallow Infaunal group dominates with between 75 – 100 % of the assemblage. The Epifaunal group makes up the remainder, with other groups showing minimal occurrence. The assemblages can be seen to coincide with this large shift in morphogroups between 3040 and 3030 m.

Epifaunal (0 to 1 cm)	*Pyrgo magnacaudata*	*Lenticulina* aff. *multinodosa*
	Pyrgo sp.	*Lenticulina americana*
Cibicidoides crebbsi	*Quinqueloculina triangularis*	*Lenticulina formosa*
Cibicidoides dohmi	*Quinqueloculina triloculiniforma*	*Lenticulina* sp.
Cibicidoides grimsdalei	*Valvulineria pseudotumeyensis*	*Sphaeroidina bulloides*
Cibicidoides guazumalensis		*Uvigerina hispida*
Cibicidoides havanaensis	**Shallow infaunal (0 to 2 cm)**	*Uvigerina* aff. *mediterranea*
Cibicidoides mundulus		*Uvigerina carapitana*
Cibicidoides pachyderma	*Bolivina multicostata*	*Uvigerina macrocarinata*
Cibicidoides sp.	*Bolivina* sp.	*Uvigerina mantaensis*
Cibicidoides sp.1	*Bolivina tenuisstraita*	*Uvigerina proboscidea*
Globocassidulina subglobosa	*Brazilina* cf. *barbata*	*Uvigerina* sp.
Gyroidina orbicularis	*Brizalina* aff. *inflata*	*Uvigerina spinulosa*
Gyroidinoides altiformis	*Brizalina alazanensis*	
Gyroidinoides altispira	*Bulimina buchiana*	**Intermediate infaunal (1 to 4 cm)**
Gyroidinoides soldanii	*Bulimina elongata*	
Gyroidinoides sp.1	*Bulimina falconensis*	*Gyroidina umbonata*
Hanzawaia mantaensis	*Bulimina macilenta*	*Melonis pompilioides*
Hanzawaia sp.	*Bulimina marginata*	*Pullenia bulloides*
Hanzawaia sp.1	*Bulimina mexicana*	
Hoeglundina elegans	*Bulimina sculptilis*	**Deep infaunal (>4 cm)**
Neoeponides campester	*Bulimina* sp.	
Oridorsalis ex gr. *umbonatus*	*Buliminella* sp.1	*Amphimorphina stainforthi*
Oridorsalis sp.	*Cassidulina* sp.	*Nonion* sp.1
Oridorsalis umbonatus	*Cassidulinella pliocenica*	*Praeglobobulimina* aff. *socialis*
Planulina renzi	*Globocassidulina* aff. *punctata*	*Praeglobobulimina ovata*

Table 5.1 List of species placed within the calcareous morphogroups for the Miocene of Plutao-1 (Corliss 1991).

Erect epifauna M1

Bathysiphon sp.
Hyperammina elongata
Hyperammina sp.
Kalamopsis sp.
Nothia excelsa
Nothia latissima
Nothia robusta
Nothia sp.
Rhabdammina cylindrica
Rhabdammina linearis
Rhabdammina sp.
Rhabdammina sp.1
Rhizammina sp.
Tolypammina sp.

Shallow infauna globular M2a

Praesphaerammina sp.
Praesphaerammina sp.1
Psammosphaera sp.
Psammosphaera sp.1
Psammosphaera cf. *fusca*
Saccammina cf. *sphaerica*
Saccammina sp.
Saccammina sp.1

Surficial epifauna trochospiral M2b

Conglophragmium irregularis
Cribrostomoides sp.
Cribrostomoides sp.1
Cribrostomoides subglobosus
Glomospira charoides
Lituotuba lituiformis
Paratrochamminoides challengeri
Paratrochamminoides deflexiformis
Paratrochamminoides gorayskiformis
Paratrochamminoides heteromorphus
Paratrochamminoides mitratus
Paratrochamminoides olszewskii
Paratrochamminoides sp.
Paratrochamminoides sp.1
Portatrochammina profunda
Recurvoides azuaensis
Recurvoides sp.
Recurvoides sp.1
Trochammina sp.
Trochammina sp.1
Trochammina sp.2
Trochammina sp.3
Trochammina sp.4
Trochamminoides folius
Trochamminoides sp.
Trochamminoides subcoronatus

Surficial epifauna keeled M2c

Gaudryina atlantica
Vulvulina miocenica

Surficial epifauna flattened M3a

Ammodiscus aff. *peruvianus*
Ammodiscus cretaceus
Ammodiscus glabratus
Ammodiscus latus
Ammodiscus sp.
Ammodiscus sp.3
Ammosphaeroidina pseudopauciloculata
Ammosphaeroidina sp.
Glomospira aff. *serpens*
Glomospira glomerata
Glomospira gordialis
Glomospira irregularis
Glomospira sp.
Glomospira sp.1
Glomospira sp.2
Spiropsammina primula

Surficial epifauna irregular M3b

Ammolagena clavata
Discamminoides sp.1

Shallow infauna planispiral M4a

Budashevaella multicamerata
Bulbobaculites sp.1
Cyclammina cancellata
Cyclammina cancellata ssp.1
Cyclammina sp.
Cyclammina sp.1
Cyclammina sp.2
Glaphyrammina americana
Haplophragmoides carinatus
Haplophragmoides cf. *bradyi*
Haplophragmoides horridus
Haplophragmoides nauticus
Haplophragmoides sp.
Haplophragmoides sp.1
Reticulophragmium acutidorsatum
Reticulophragmium acutidorsatum ssp.1
Reticulophragmium aff. *orbicularis*
Reticulophragmium amplectens
Reticulophragmium amplectens ssp.1
Reticulophragmium gasparensis
Reticulophragmium rotundidorsatum
Reticulophragmium sp.
Reticulophragmium sp.1

Deep infauna M4b

Aschemocella grandis
Bigenerina sp.
Eggerelloides sp.1
Hormosina glabra
Hormosina globulifera
Hormosinella carpenteri
Hormosinelloides guttifer
Karreriella aff. *bradyi*
Karreriella sp.1
Karrerulina apicularis
Karrerulina sp.
Martinotiella aff. *communis*
Martinotiella sp.
Pseudonodosinella nodulosa
Reophanus berggreni
Reophax pilulifer
Reophax sp.
Subreophax scalaris
Subreophax sp.1
Textularia earlandi
Valvulina flexilis

Table 5.2 List of species placed within the agglutinated morphogroups for the Miocene of Plutao-1 (Van den Akker et al. 2000).

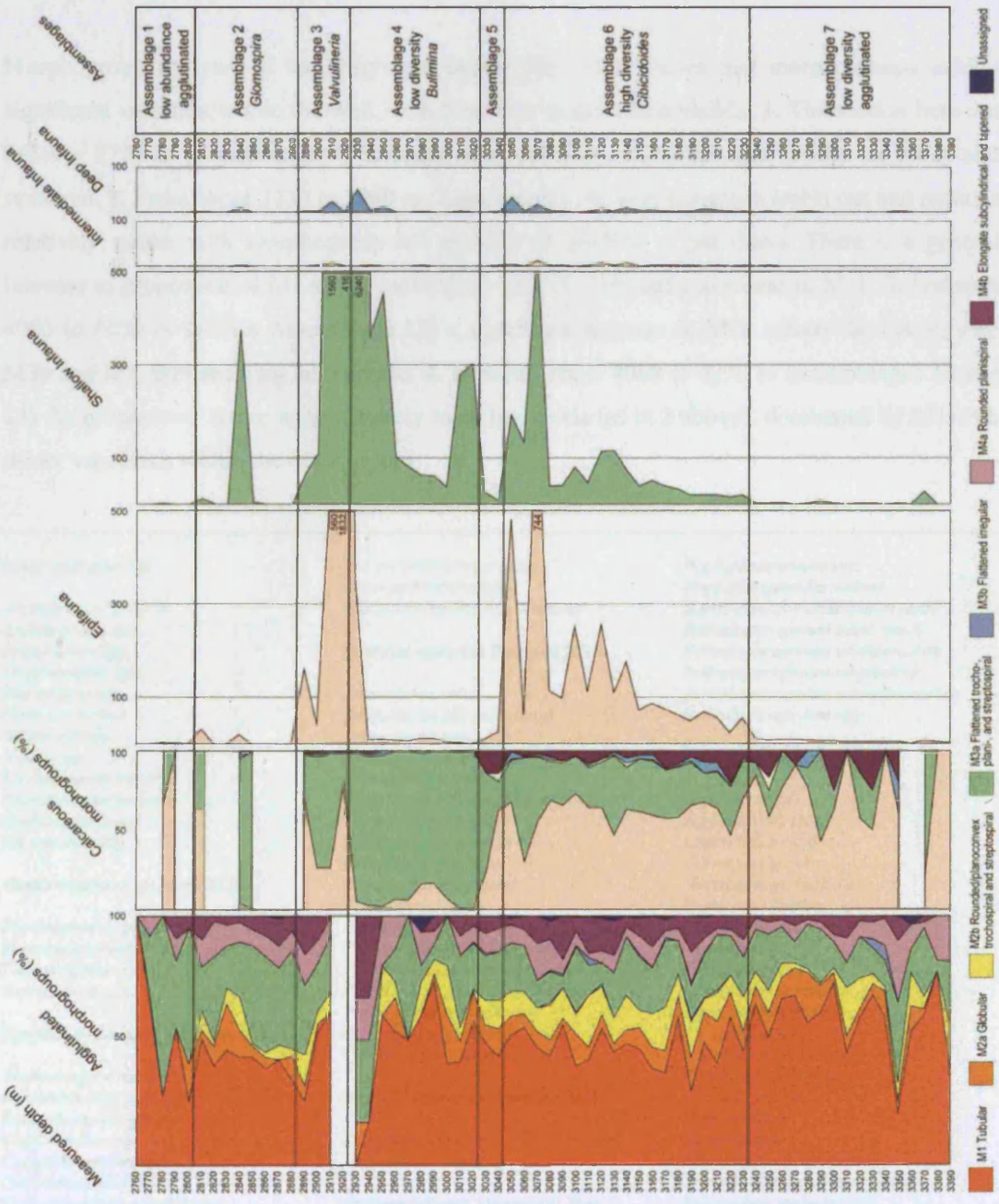


Figure 5.13 Results of morphogroups for the Miocene of Plutao-1, as percentage of total fauna for agglutinated and calcareous foraminifera, and as absolute abundances of calcareous morphogroups.

5.4.2 Oligocene

Morphogroup analysis of the Oligocene faunas (fig. 5.14) shows that morphogroups exhibit significant variation within the well, with four large-scale trends visible: **1.** The section between 3630 to 3720 m (Assemblage 9) contains very low abundances and thus results are noisy and scattered. **2.** From about 3730 to 3990 m (Assemblages 10 – 12) the graph levels out and remains relatively stable, with morphogroup M1 making up 35-70% of the fauna. There is a general increase in proportion of M1 as we move down this section, and a decrease in M2b. **3.** Between 4000 to 4050 m (within Assemblage 13) a significant increase in M4b offsets the curve, with M3b and M1 also showing an increase. **4.** Between about 4060 to 4270 m (assemblages 13 and 14) the proportions return approximately to earlier levels (as in 2 above), dominated by M1 with minor variations within the other groups.

Erect epifauna M1

Aschemocella grandis
Aschemocella spp.
Bathysiphon spp.
Hyperammina spp.
Kalamopsis spp.
Nothia latissima
Nothia robusta
Nothia spp.
Rhabdammina linearis
Rhabdammina scalaria
Rhabdammina spp.
Rhizammina spp.

Shallow infauna globular M2a

Placentammina placenta
Praesphaerammina spp.
Psammosphaera spp.
Saccammina spp.

Surficial epifauna trochospiral M2b

Ammomarginulina spp.
Boudashevaella multicamerata
Boudashevaella spp.
Caudammina spp.
Congophragmium spp.
Cribrostomoides spp.
Cribrostomoides subglobosus
Paratrochamminoides irregularis
Portatrochammina profunda
Recurvoides azuaensis
Recurvoides spp.
Trochammina aff. *proteus*
Trochammina spp.
Trochamminoides proteus
Trochamminoides spp.
Trochamminoides subcoronatus

Surficial epifauna flattened M3a

Ammodiscus latus
Ammodiscus aff. *peruvianus*
Ammodiscus spp.
Ammodiscus tenuissimus
Ammosphaeroidina spp.
Glomospira aff. *irregularis*
Glomospira charoides
Glomospira glomerata
Glomospira gordialis
Glomospira irregularis
Glomospira spp.
Lituotuba lituiformis
Paratrochamminoides gorayskiformis
Paratrochamminoides gorayskii
Paratrochamminoides olszewskii
Paratrochamminoides spp.
Spiropsammina primula
Trochamminoides sp. 2

Surficial epifauna irregular M3b

Ammolagena clavata
Discamminoides sp.1

Shallow infauna planispiral M4a

Cyclammina aff. *orbicularis*
Cyclammina sp. 1
Cyclammina spp.
Glaphyrammina americana
Haplophragmoides nauticus
Haplophragmoides spp.
Haplophragmoides walteri
R.amplectens/acutidorsatum trans.
Reticulophragmium acuti. var. 1
Reticulophragmium acutidorsatum
Reticulophragmium amplectens
Reticulophragmium rotundidorsatum
Reticulophragmium spp.

Deep infauna M4b

Bigenerina spp.
Eggerelloides sp.1
Eggerelloides spp.
Hormosina glabra
Hormosina globulifera
Hormosina guttifer
Hormosina spp.
Jaculella spp.
Karreriella spp.
Karrerulina apicularis
Karrerulina conversa
Karrerulina spp.
Pseudonodosinella spp.
Reophanus berggreni
Reophax pilulifer
Reophax sp. 1
Reophax spp.
Scherochorella congoensis
Spiroplectammina navaroanna
Subreophax scalaris
Subreophax spp.
Textularia earlandi
Valvulina flexilis
Valvulina sp. 1
Verneuilina spp.

Table 5.3 List of species placed within the agglutinated morphogroups for the Oligocene of Plutao-1 (Van den Akker et al. 2000).

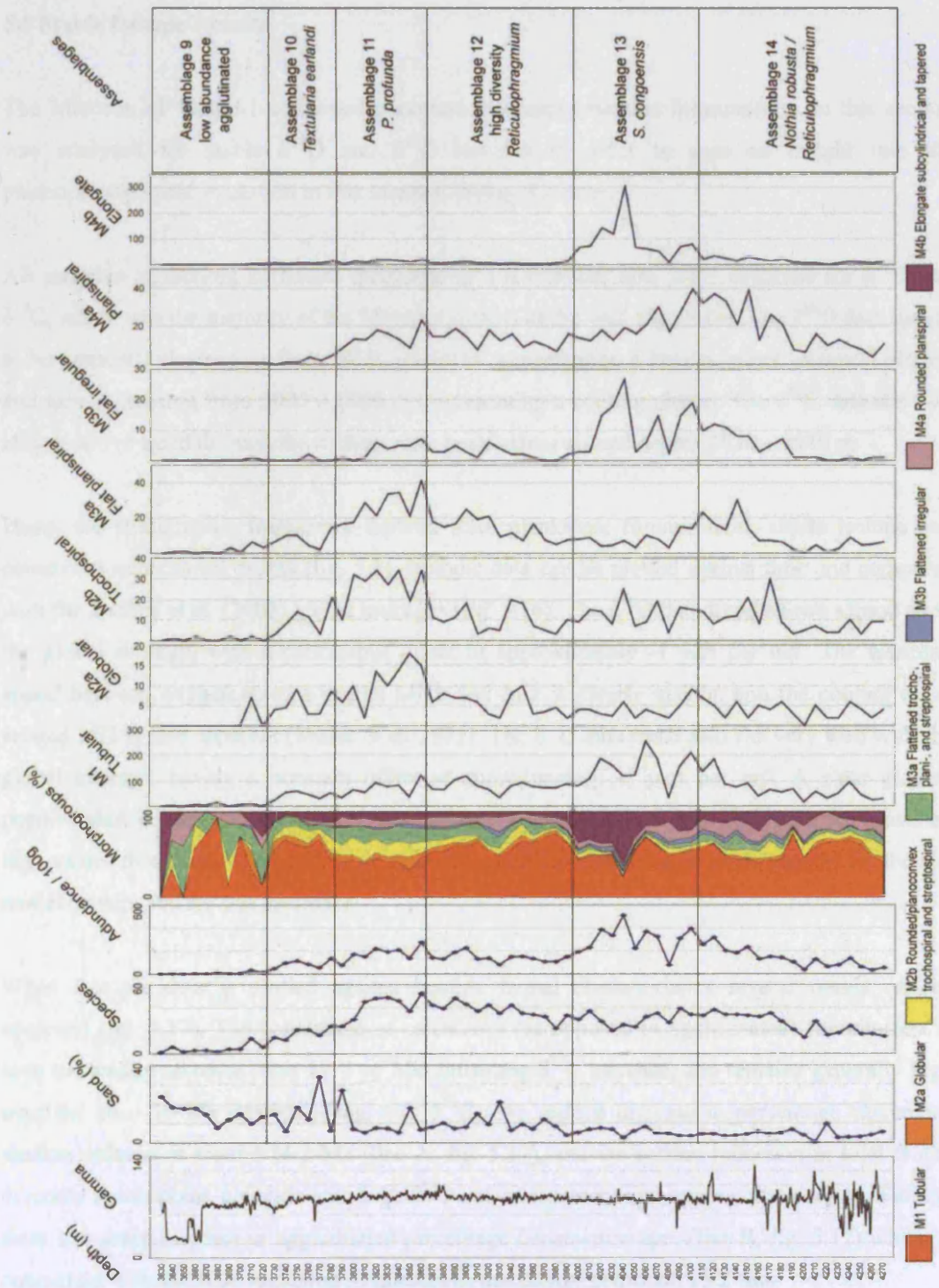


Figure 5.14 Results of morphogroups for the Oligocene of Plutao-1, against depth, gamma and interpreted assemblages. Morphogroups given both as a percentage of total fauna, and as absolute counts. Abundance and diversity also shown.

5.5 Stable Isotope Results

The Miocene of Plutao-1 contained persistent calcareous benthic foraminifera, so this section was analysed for stable $\delta^{18}O$ and $\delta^{13}C$ isotopes in order to gain an insight into the palaeoceanographic evolution in this location during this time.

All samples containing sufficient quantities of *Cibicidoides* spp. were analysed for $\delta^{18}O$ and $\delta^{13}C$, which was the majority of the Miocene section of the well (fig. 5.15). The $\delta^{18}O$ data appear to be generally decreasing from 3420 – 3100 m (representing a bottom-water warming phase), and then increasing from 3090 – 2800 m (representing a cooling phase). The $\delta^{13}C$ data shows a clear positive trend through the section, with peak values around depths 3030 – 2910 m.

Using the stratigraphic framework derived from planktonic foraminiferal, stable isotope and calcareous nannofossil events (fig. 5.1), isotopic data can be plotted against time and compared with the Zachos et al. (2001) global averages (fig. 5.16). The $\delta^{18}O$ data trend shows a good fit to the global average, with a continuous offset of approximately -1 part per mil. The warming signal between oxygen isotope events Mi1b and Mi2 is clearly visible, and the cooling event around Mi2 is also apparent (Miller et al. 1991). The $\delta^{13}C$ data trend also fits very well with the global average, having a constant offset of approximately -1 part per mil. A clear gradual positive shift in values from around 19 – 16 Ma is apparent in both records, as are the sustained high values thereafter. The good fit of these data with the global signal lends support for the age model constructed for this section.

When isotopic data is plotted against benthic faunal characteristics several trends can be observed (fig. 5.17). The percentage of calcareous (as opposed to agglutinated) foraminifera is seen to steadily increase from 19 – 16 Ma, mirroring $\delta^{13}C$ increase, and remains generally high over the 16 – 15 Ma interval along with $\delta^{13}C$. The sudden increase in percentage calcareous shallow infauna at around 16.2 Ma (line A, fig. 5.17), and the sudden reduction in total faunal diversity at this point, coincide with high $\delta^{18}O$ values representing bottom water cooling. Finally, there is a sharp increase in agglutinated percentage *Glomospira* spp. (line B, fig. 5.17) which is concurrent with the final reduction in calcareous percentage at around 15.2 Ma.

Isotope data has also been plotted against foraminiferal abundance, sedimentation rate and the Haq et al. (1987) global sea level curve (fig. 5.18). Two large peaks in abundance occur at approximately 16 and 15 Ma, coinciding with the two large falls in sea level at transgressive

boundaries TB2.3 and TB2.4. These levels occur during times of increased $\delta^{13}C$ and increased $\delta^{18}O$ levels. Sedimentation rate is also highest over the same interval, with levels rising from an average of 6 cm/kyr before TB2.3 to an average of 20 cm/kyr thereafter.

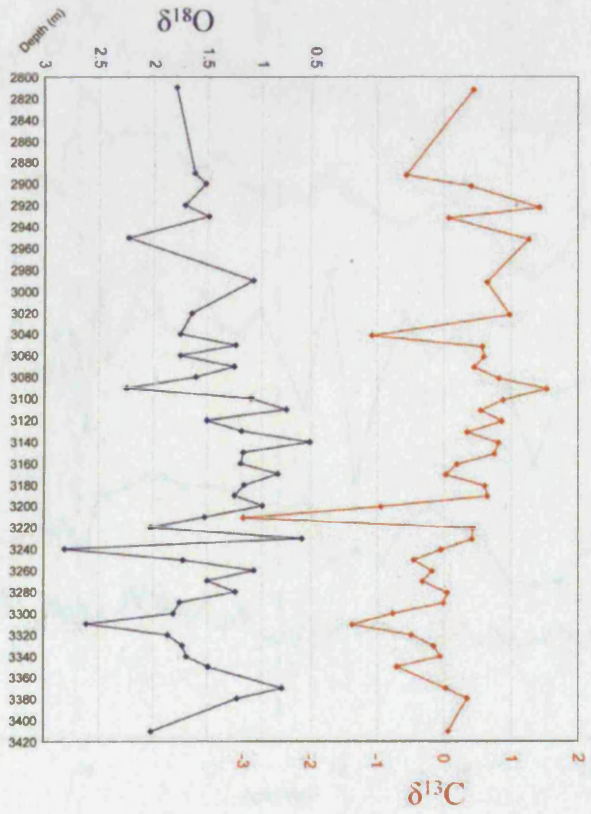


Figure 5.15 Raw oxygen and carbon isotope data (from *Cibicidoides* spp.) against depth for the Miocene section of Plutao-1.

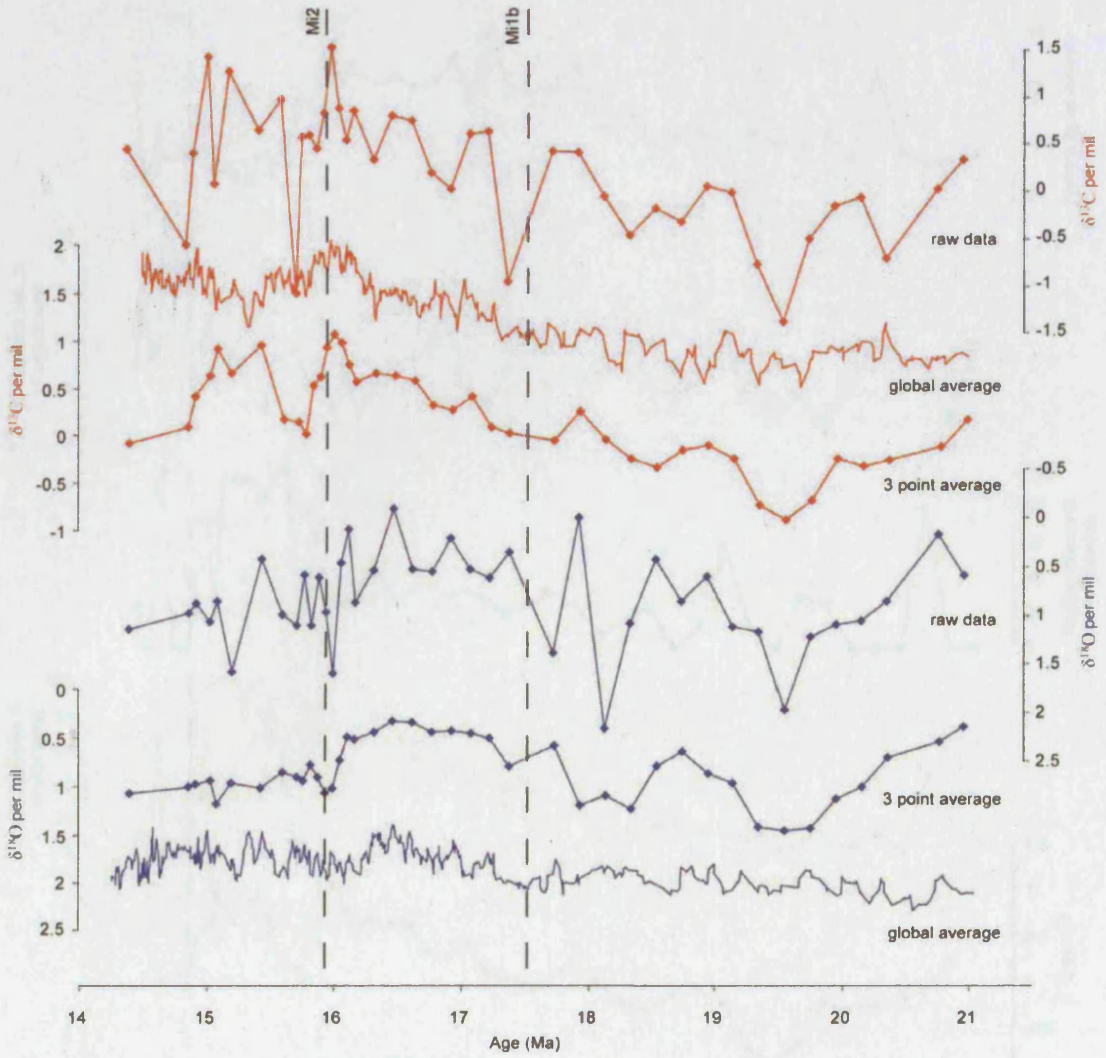


Figure 5.16 Oxygen and carbon isotope data against time, compared with the global curves of Zachos et al. (2001). Both 3 point average and global average data is shown on same axis. Oxygen isotope events Mi2 and Mi1b (Miller et al. 1991) are also shown.

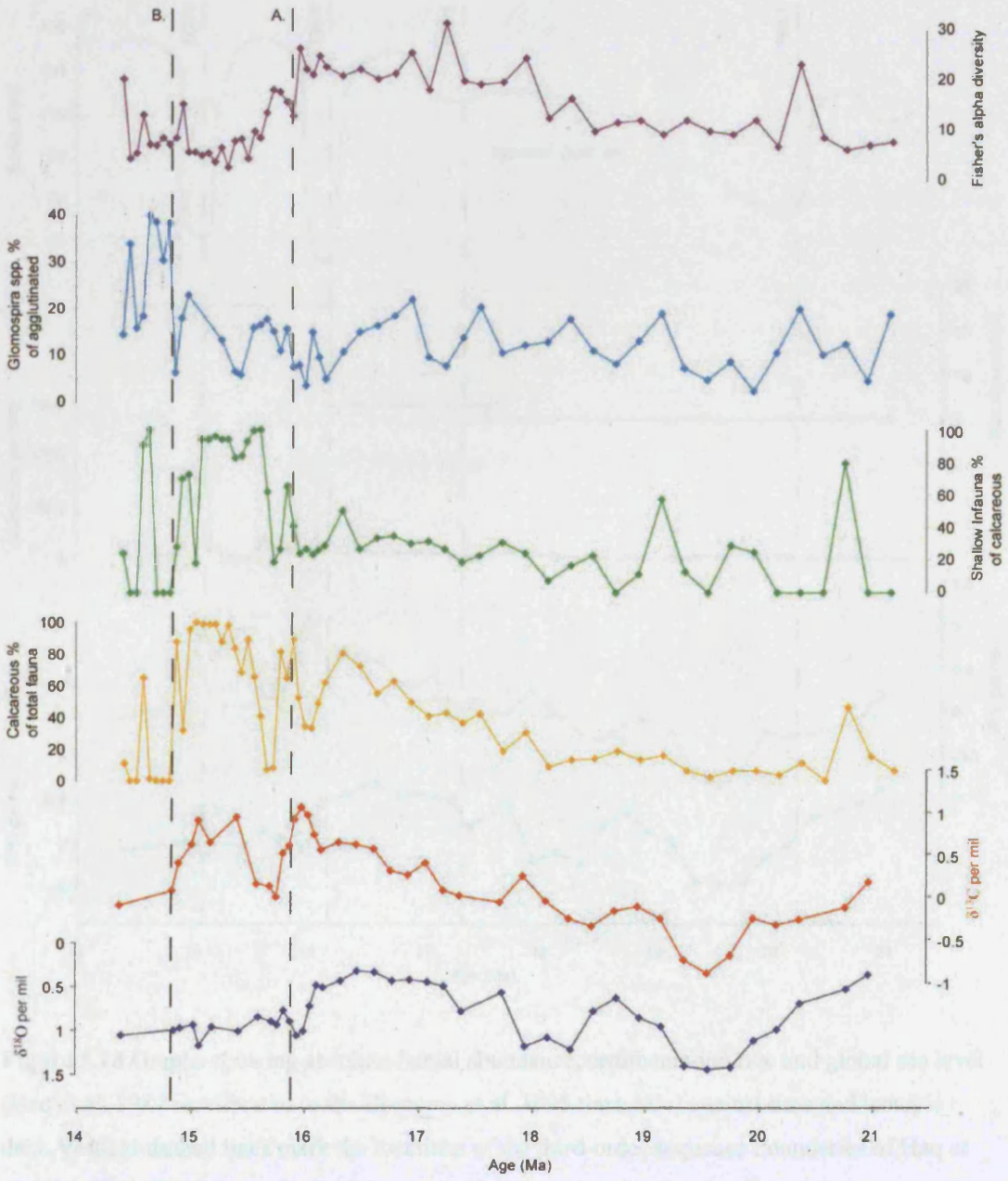


Figure 5.17 Graphs showing abundance, diversity and faunal characteristics against time and isotope curves. Line **A** marks the onset of infaunal increase, diversity decrease and $\delta^{18}O$ increase. Line **B** marks the increase in *Glomospira* spp. and the decrease in calcareous content.

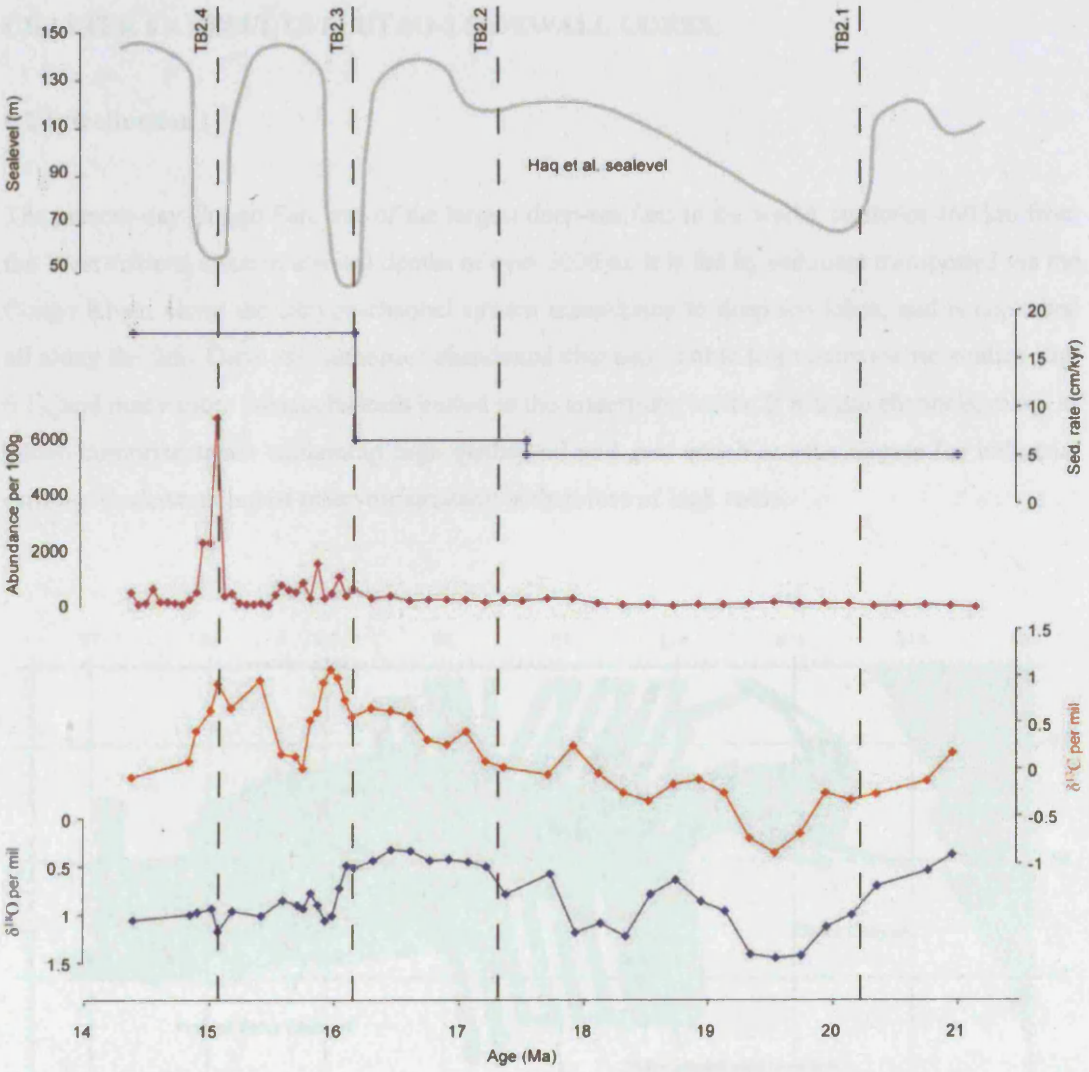


Figure 5.18 Graphs showing absolute faunal abundance, sedimentation rate and global sea level (Haq et al. 1987 recalibrated to the Berggren et al. 1995 timescale) against time and isotopic data. Vertical dashed lines mark the locations of the third-order sequence boundaries of Haq et al. (TB2.1 to TB2.4).

CHAPTER 6 – RESULTS PLUTAO-1 SIDEWALL CORES

6.1 Introduction

The present-day Congo Fan, one of the largest deep-sea fans in the world, stretches 760 km from the West African coast to abyssal depths of over 5000 m. It is fed by sediment transported via the Congo River, along the canyon-channel system meandering to deep sea lobes, and is deposited all along the fan. There are numerous abandoned channels visible from bathymetric studies (fig. 6.1), and many more palaeochannels buried in the underlying strata. It is these channels, many of which comprise sands containing high quality oil and gas, which are the targets for industrial drilling. Understanding of reservoir structure is therefore of high value.

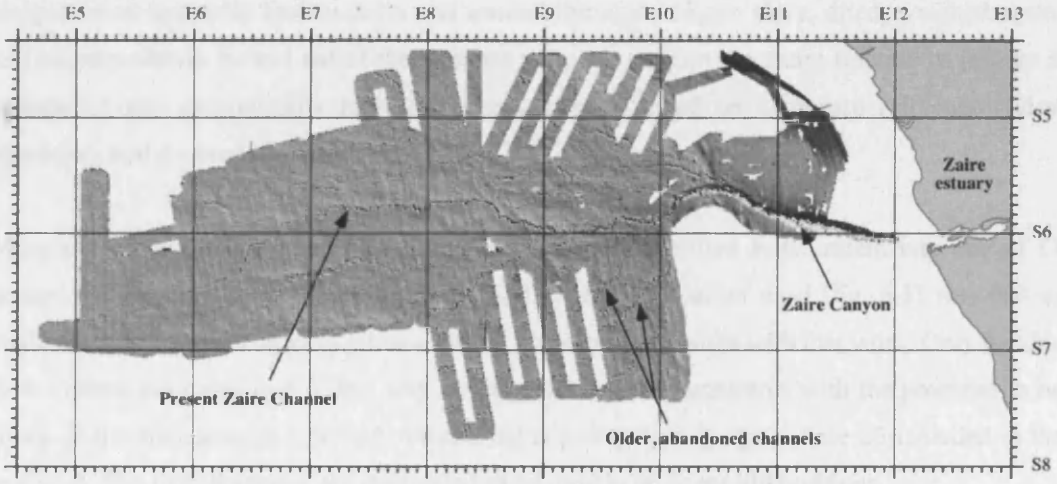


Figure 6.1 Bathymetric map of the Congo Fan showing the sinuous and far-reaching present-day channel and canyon (Babonneau et al. 2002).

Ditch cutting samples at 10 m intervals were analysed through the channel complex of Plutao-1 (3670 – 3370 m), but contained only barren sandy horizons. A total of 37 sidewall core samples were also collected from within this level, and provided by BP for analysis. They were found to contain a significant fauna. The importance of these samples is high, and the aims of this section are two-fold: 1) to obtain a stratigraphic age for this section, from which the ditch cuttings returned only barren samples, 2) to identify architectural elements of the channel system from the

microfaunal signature. A detailed study of the microfauna from channel sediment outcrops was carried out as part of a PhD thesis by Dellamonica (2004), and Jones et al. (2005) and Smith and Gallagher (2003) also studied outcrops of channel sediments for microfossil content. This study aims to build upon our current understanding.

6.2 Materials and Methods

Sidewall cores (small horizontal cores taken from the sides of boreholes by wireline tool instruments) from 38 horizons were analysed from Plutao-1 for their foraminiferal content. The cores contained varying amounts of recovery, from no recovery to a maximum of 150 g when weighed (fig. 6.2). The small sections of rock (approximately 3 cm diameter by 10 cm length at maximum recovery) were almost exclusively mudstone and siltstone in composition, the sandy horizons presumably being lost on recovery due to weak lithification. After weighing, the samples were manually broken-down and washed through a 63 μm sieve, dried, weighed again, and all microfossils picked out of the remaining residue or from the entire fraction of residue if abundance was exceptionally high. Specimens were mounted on cardboard reference slides, identified, and counted (Appendix 5).

Morphogroup analysis was carried out by placing each identified foraminifera into one of 11 groups based on gross morphology (Table 6.1). The classification used (fig. 6.3) was that of Dellamonica (2004), in order to allow a direct comparison of results with that work. Only benthic foraminifera were analysed in this way, as they are the only organisms with the potential to be living in the environment (although transported and reworked specimens are all included in the analysis). The morphogroups are interpreted as relating to different life positions.

Foraminiferal diversity was estimated using Fisher's alpha diversity index (αx) (see section 4.6.1), which was calculated using the software of Hammer et al. (2005). The same software was also used to calculate results for Correspondence Analysis (see section 4.6.3).

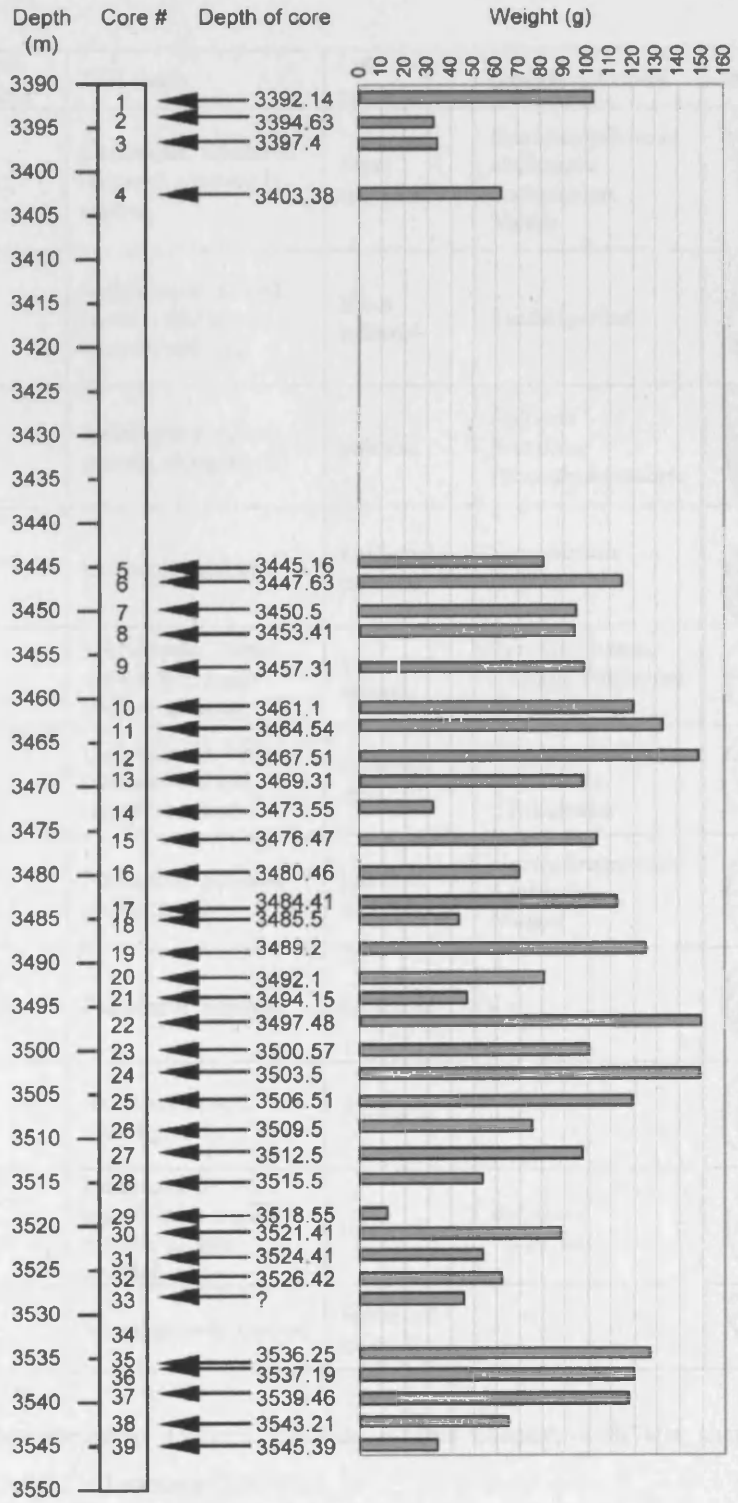


Figure 6.2 Location and weights of the 38 sidewall cores analysed from Plutao-1. The section spans submarine channel sands.

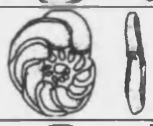
Morpho-groups	Sub-groups	Test shape	Life position	Generic examples	Morphology
A	A1	Unilocular, tubular to uniserial, circular in section	Erect epifaunal	*Psammosiphonella, Nodosaria, Bathysiphon, Nothia*	
	A2	Multilocular, mixed growth, tending to become uniserial	Erect infaunal	*Rectuvigerina*	
B	B	Multilocular, mixed growth, elongate flat	Infaunal	*Bolivina, Brizalina, Plactofrondicularia*	
C	C1	Unilocular globular	Epifaunal / infaunal	*Saccammina, Lagena*	
	C2	Multilocular, mixed growth tending to become globular	Epifaunal / infaunal	*Ceratobulimina, Praeglobobulimina, Sphaeroidina*	
D	D	Unequally biconvex, planoconvex and concavoconvex	Epifaunal attached	*Trochammina, Hanzawaia, Cibicidoides*	
E	E1	Planispiral, rounded biconvex	Infaunal / epifaunal	*Haplophragmoides, Lenticulina, Nonion*	
	E2	Planispiral discoidal	Epifaunal	-	
F	F	Biconvex keeled, mixed growth	Epifaunal	-	
G	G1	Unilocular to multilocular mixed growth, prolate rounded	Infaunal	*Bulimina, Uvigerina*	
	G2	Mixed growth, tapered	Epifaunal / infaunal	-	

Figure 6.3 Morphogroup analysis followed in this chapter, with test shape and inferred microhabitat. After Dellamonica (2004).

A1	**C1**	*Cibicidoides* spp.
Bathysiphon spp.	*Placentammina placenta*	*Neoeponides campester*
Psammosiphonella cylindrica	*Saccamina sphaerica*	*Oridorsalis umbonatus*
Nothia latissima	*Lagena striata*	*Valvulinaria pseudotumeyensis*
Neugeborina longiscata	**C2**	*Valvulinaria* spp.
Nodosaria anomala	*Ceratobulimina alazanensis*	**E1**
Pygmaeoseistron sp.	*Megastomella africana*	*Haplophragmoides* spp.
Nodosaria sp.	*Praeglobobulimina* sp.	*Reticulophragmium rotundidorsatum*
A2	*Sphaeroidina bulloides*	*Lenticulina* spp.
Rectuvigerina sp.	**D**	*Nonion* sp. 1
Rectuvigerina stonei	*Ammonia* sp.	*Nonion* sp. 2
B	*Trochammina* spp.	*Nonion* spp.
Bolivina sp.	*Hanzawaia* aff. *americana*	**G1**
Brizalina aff. *inflata*	*Hanzawaia* sp.	*Bulimina elongata*
Brizalina alazanensis	*Cibicidoides crebbsi*	*Bulimina falconensis*
Brizalina cf. *barbata*	*Cibicidoides grimsdalei*	*Bulimina* sp.
Plectofrondicularia longistriata	*Cibicidoides havanensis*	*Uvigerina* aff. *mediteranea*
Plectofrondicularia morreyae	*Cibicidoides mundulus*	*Uvigerina carapitana*
Plectofrondicularia spp.	*Cibicidoides perlucidus*	*Uvigerina spinulosa*
		Uvigerina spp.

Table 6.1 List of all benthic species included in each morphogroup. Morphogroups after Dellamonica (2004).

6.3 Biostratigraphy

The potential problem of younger material caving down-hole (a frequent issue with ditch cutting samples) is not encountered here as the samples are cores, and so stratigraphically younger material should never show up. Stratigraphically older material can however be expected since in channel systems reworking is common. Biostratigraphic analysis must therefore be based on the youngest age observed within the samples.

The age of the sidewall core samples range from Upper Oligocene to Lower Miocene (fig. 6.4), as determined from calcareous nannofossils by Tania Micoara of Babeş-Bolyai University, Cluj-Napoca, Romania. The CN1b / CN1c boundary is interpreted as between samples S16 and S15 based on the occurrences of *Cyclicargolithus abisectus* (Müller) in sample S16, and *Discoaster*

druggii (Bramlette and Wilcoxon) in sample S14 (Bown 1998). The Oligocene / Miocene boundary occurs a little below this (Bown 1998), interpreted to be around samples S16 – S18.

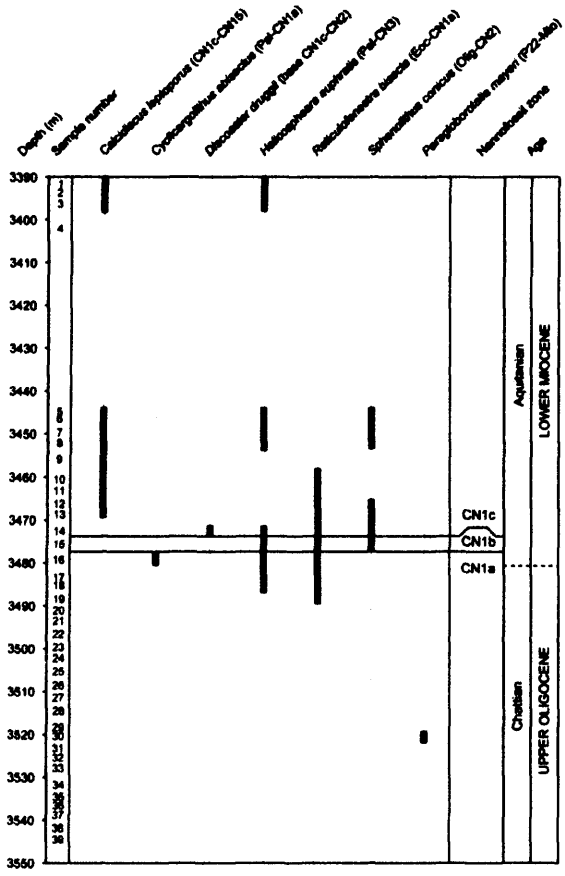


Figure 6.4 Biostratigraphy of sidewall core samples. Nannofossils by Tania Micoara (Babeş-Bolyai University, Cluj-Napoca, Romania). Species zonal ranges from Bown (1998).

Planktonic foraminifera are poorly preserved and identification of most specimens is difficult (see Appendix 5). The only stratigraphically useful species encountered is *Paragloborotalia mayeri* (Cushman and Ellisor) sensu Bolli and Saunders (1985) in sample S30, which was recorded down to base N4 (23 Ma) by Kennett and Srinivasan (1983), and base P22 (26.8 Ma) by Bolli and Saunders (1985). Sample S30, near the base of the section, is therefore no older than 26.8 Ma (mid-Chattian). The top of the section is probably no younger than Aquitanian, based on the analysis of ditch cutting samples from overlying strata (see Chapter 5). All ages used are from the timescale of Lourens et al. (2004).

6.4 Foraminiferal Abundance and Diversity

A relatively low diversity assemblage was obtained from the sidewall core samples, with varying abundance and composition (figs 6.5, 6.6, Appendix 5). Preservation is in general very bad, with small robust specimens showing abrasion and dominating most samples. Planktonic foraminifera comprise the highest percentage of specimens in many samples, followed by small trochospiral and planispiral calcareous foraminifera. Agglutinated foraminifera are rare in most samples. Radiolarians also occur in high abundance.

The samples showing lowest abundance are at the top and bottom of the section (samples S39 – S26, 3545 – 3509 m and S5 – S1, 3445 – 3392 m) with generally far less than 100 specimens per 100 g. The greatest abundance occurs in samples S12 – S10 (3468 – 3461 m) with over 2000 specimens per 100 g, the remaining samples having between 250 – 1000 specimens per 100 g. Samples containing the highest abundances also generally contain the highest number of species and diversity (Fisher's αx), apart from samples S9 – S6 (3458 – 3447 m) which have low abundance but the highest diversity.

The dominating species within the section of high abundance (S16 – S6, 3481 – 2447 m) are *Nonion* spp., *Cibicidoides perlucidus* (Nuttall), *Hanzawaia* aff. *americana* (Cushman) and *Valvulineria* spp. Other species sporadically dominate samples above and below this interval, along with many barren samples.

6.5 Morphogroup Results

Benthic foraminifera were placed into morphogroups based on test shape (fig. 6.3), the results of which are shown in figure 6.7. Epifaunal morphogroups D and E1 dominate samples S16 – S6, with samples S16 – S12 more dominated by group D than samples S11 – S6. Samples S39 – S18 at the bottom of the section show sporadic domination by several morphogroup (A1, B, C1), which is a pattern repeated in samples S5 – S1 at the top of the section (morphogroups A1, B, C2, E1). The infaunal morphogroup G1 shows low percentages throughout the entire section.

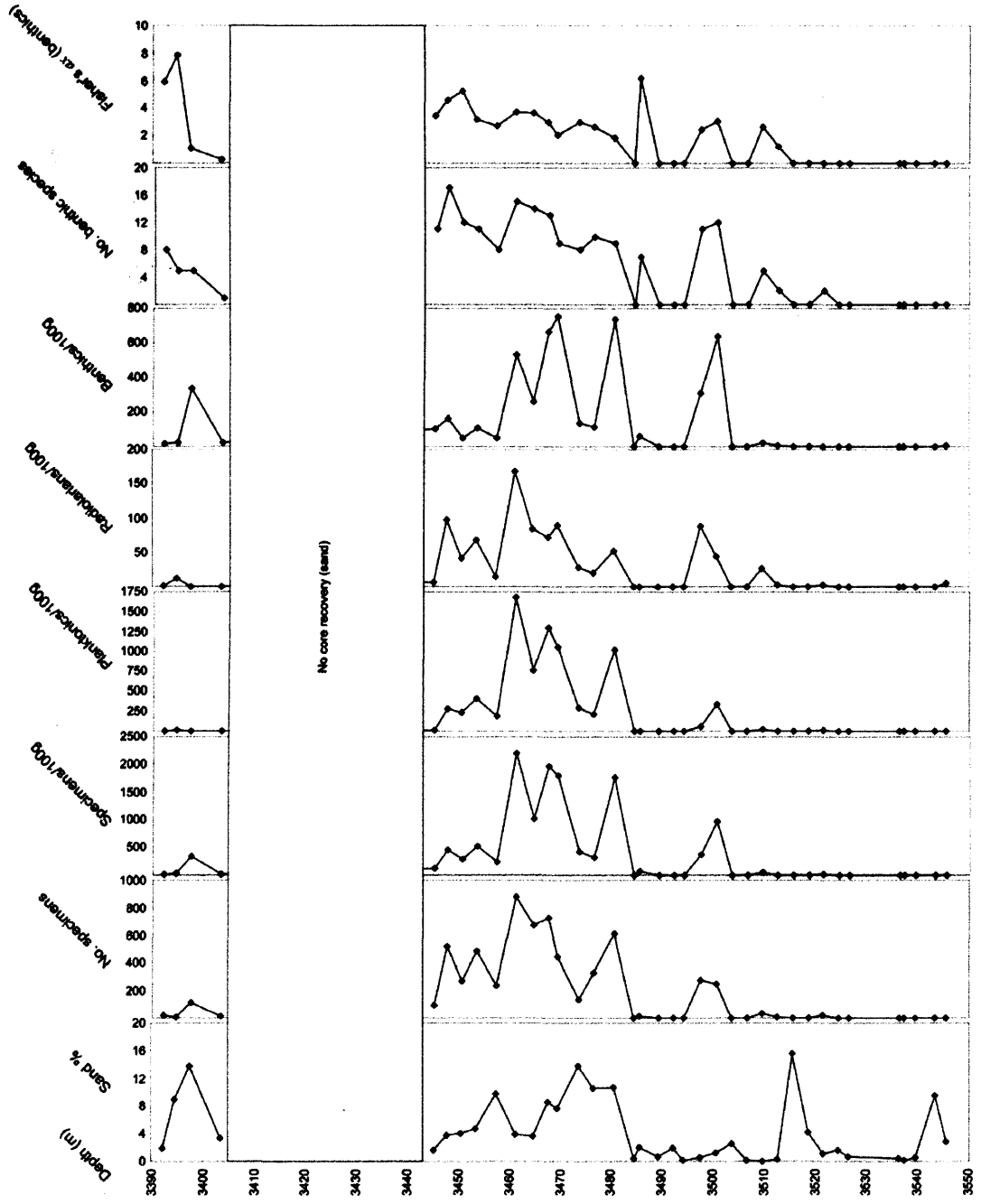


Figure 6.5 Faunal characteristics and measured sand content in each sample are given against depth. Fisher's αx is given for benthic foraminifera only.

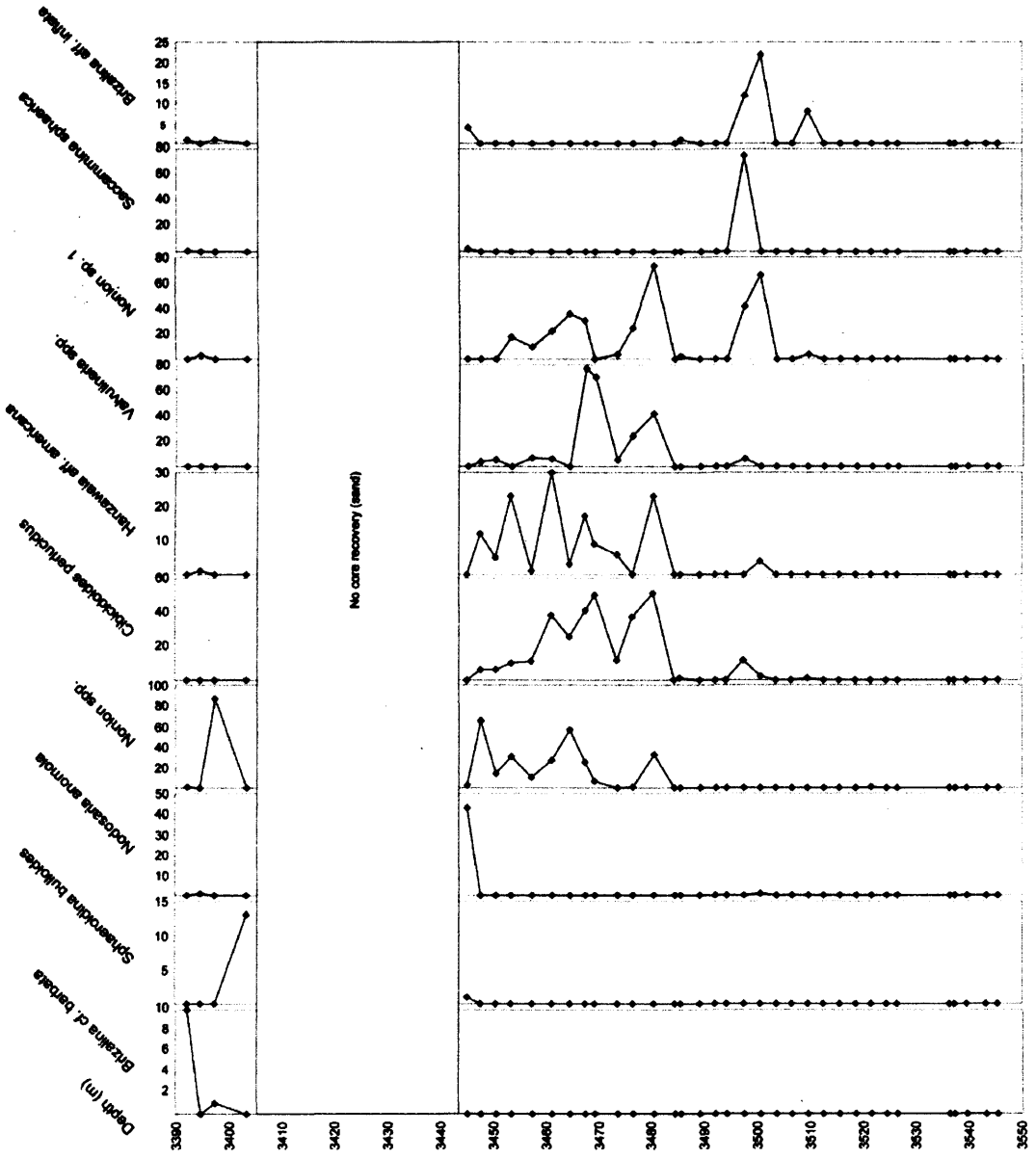


Figure 6.6 Graphs showing the varying abundance of selected species in each sample against depth. Values are raw counts.

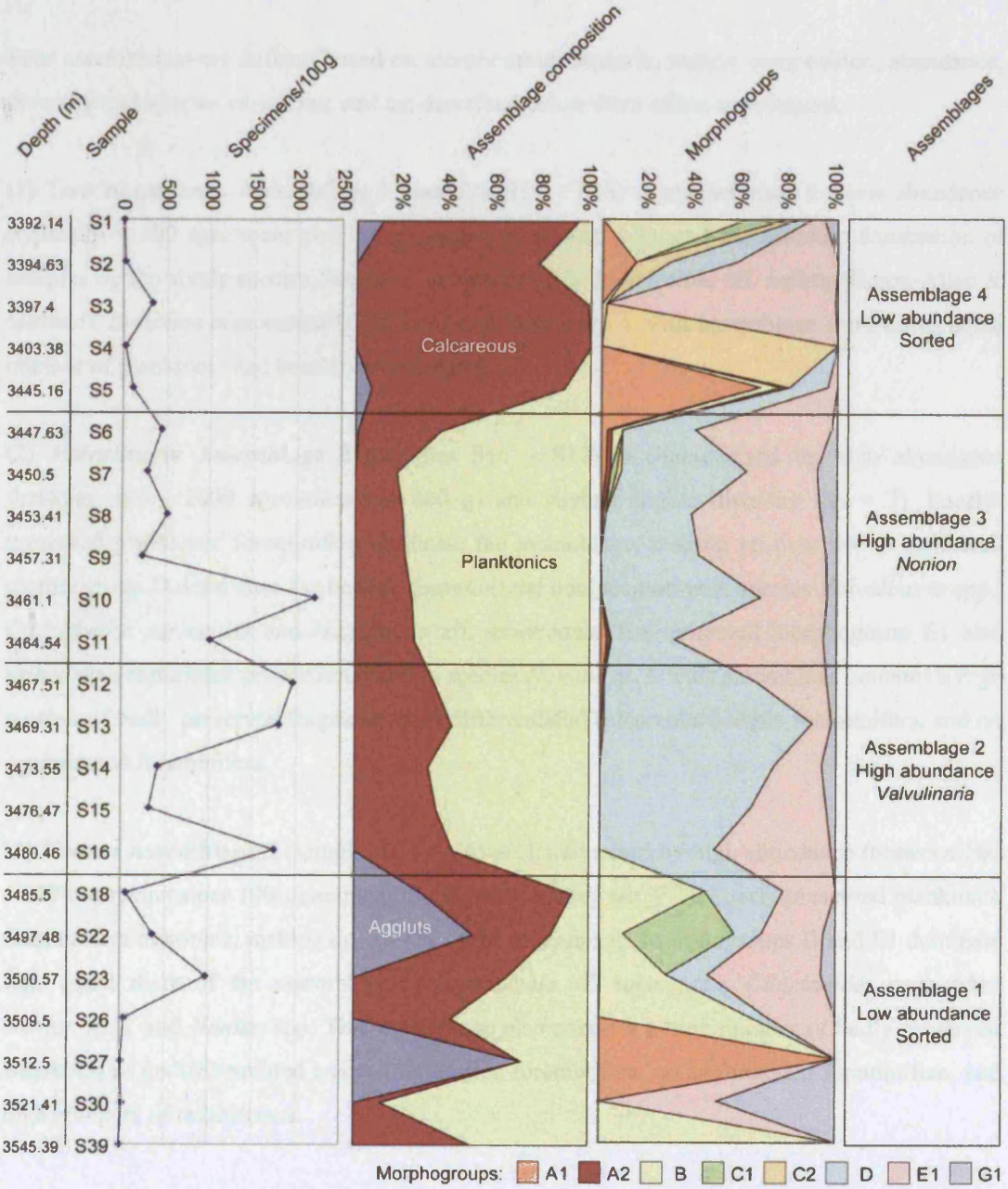


Figure 6.7 Morphogroups and assemblages of foraminifera, against sample composition and absolute abundance. Only samples containing benthic foraminifera are included in the morphogroup analysis.

6.6 Assemblages

Four assemblages are defined based on morphogroup analysis, sample composition, abundance, diversity and species variations, and are described below from oldest to youngest:

(1) Low abundance Assemblage 1 (samples S39 – S18) is characterised by low abundance (typically < 100 specimens per 100 g) and diversity ($\alpha x \leq 1$), and the sporadic domination of samples by the single species *Saccammina sphaerica* Sars, *Brizalina* aff. *inflata* (Heron-Allen & Earland), *Brizalina alazanensis* (Cushman) and *Nonion* sp. 1. This assemblage contains an equal number of planktonic and benthic foraminifera.

(2) *Valvulineria* Assemblage 2 (samples S16 – S12) is characterised by high abundance (between 400 - 2000 specimens per 100 g) and slightly higher diversity ($\alpha x = 2$). Poorly-preserved planktonic foraminifera dominate the assemblage, making up over 60 %. Epifaunal morphogroup D dominates the benthic foraminiferal composition with species *Valvulineria* spp., *Cibicidoides perlucidus* and *Hanzawaia* aff. *americana*. The epifaunal morphogroup E1 also makes up a significant proportion with the species *Nonion* sp. 1. This assemblage contains a high number of badly preserved fragments of undifferentiated calcareous benthic foraminifera, and no agglutinated foraminifera.

(3) *Nonion* Assemblage 3 (samples S11 – S6) is characterised by high abundance (between 200 – 2000 specimens per 100 g) and slightly higher diversity ($\alpha x \geq 2$). Poorly-preserved planktonic foraminifera dominate, making up ~ 80 % of the assemblage. Morphogroups D and E1 dominate with equal share of the assemblage by *Hanzawaia* aff. *americana*, *Cibicidoides perlucidus*, *Nonion* sp. 1 and *Nonion* spp. This assemblage also contains a high number of badly preserved fragments of undifferentiated calcareous benthic foraminifera, no agglutinated foraminifera, and high numbers of radiolarians.

(4) Low abundance Assemblage 4 (samples S5 – S1) is characterised by low abundance (typically < 50 specimens per 100 g) and varying diversity, and the sporadic domination of samples by the single species *Brizalina* cf. *barbata* (Phleger & Parker), *Nodosaria anomala* Reuss, *Sphaeroidina bulloides* d'Orbigny and *Nonion* spp. This assemblage contains very few planktonic foraminifera.

6.7 Correspondence Analysis

Correspondence Analysis carried out on the entire data set (fig. 6.8) shows a clustering of Assemblages 2 and 3 around negative axis 1 and 2 values, and the dispersion of samples from the higher part of the section (S5, S4, S1) and lower part (S22, S27, S39) towards higher axis 1 and axis 2 values. The species corresponding to these samples include *S. bulloides*, *N. anomala*, *B.* cf. *barbata* and *S. sphaerica*. These samples, from Assemblages 1 and 4, are expected to be separated from each other in this analysis because the definition of these assemblages is their varying nature. Conversely, Assemblages 2 and 3 are defined on the similarity of their fauna and are therefore clustered.

Samples from Assemblages 2 and 3 were analysed separately (fig. 6.9) in order to gain a more detailed insight into these two rather similar assemblages. Species with abundances of 3 or less were also removed from the analysis to aid clarity. Samples from Assemblage 2 can be seen to cluster around negative axis 2 values, whilst Assemblage 3 samples cluster together around positive axis 2 values. As expected, species *Valvulineria* spp., *C. perlucidus* and *Nonion* sp. 1 are associated with Assemblage 2 by having negative axis 2 values, and species *Nonion* spp., *Hanzawaia* spp. and *H.* aff. *americana* are associated with Assemblage 3 by having positive axis 2 values.

Correspondence Analysis can be seen to support the assemblage designations made using morphogroup analysis, sample composition, abundance, diversity and species variations, and offers independent statistical evidence for this interpretation.

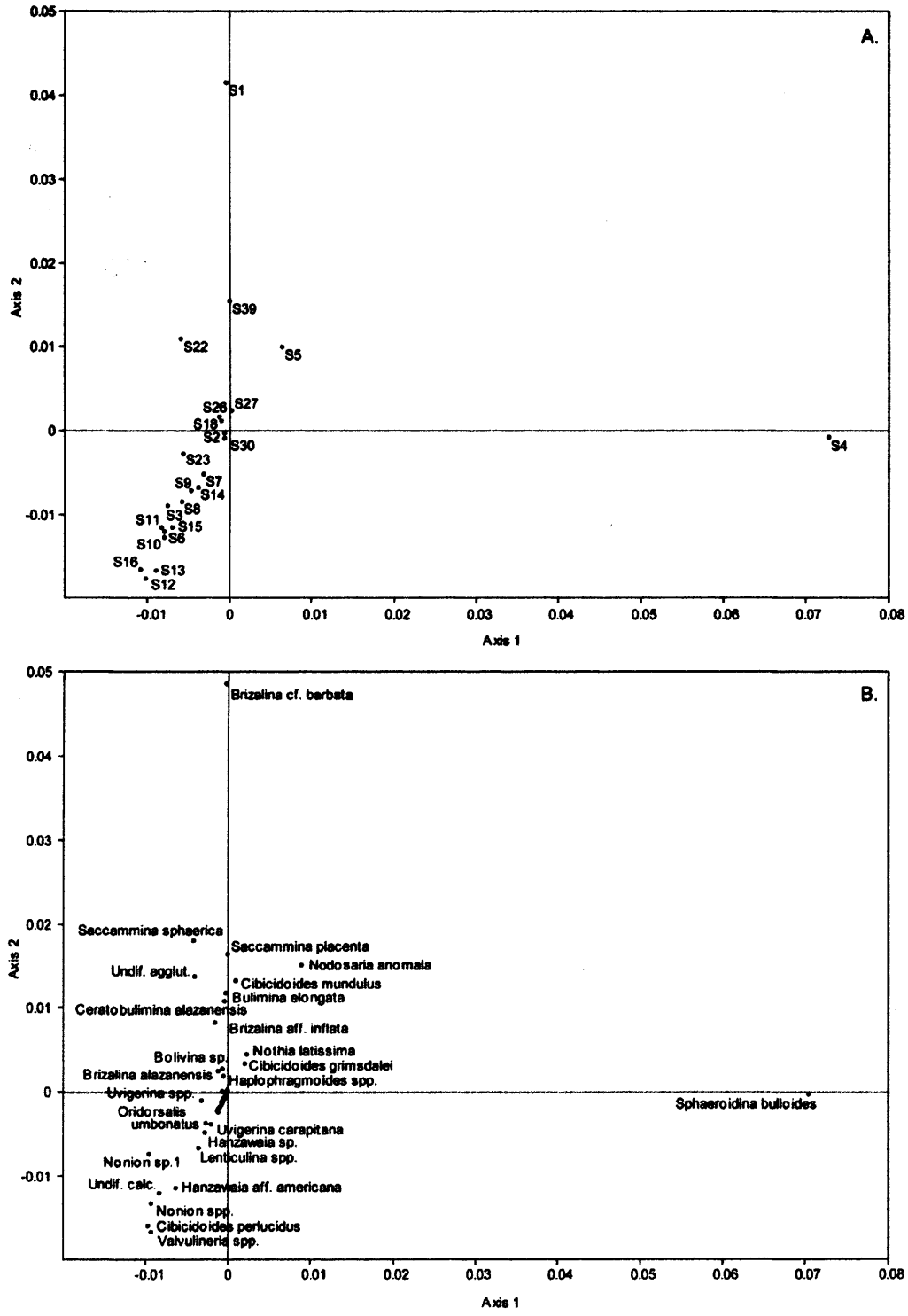


Figure 6.8 Results of Correspondence Analysis for the entire data-set (sidewall cores – Plutao-1). Shows positions of **A** samples S1 – S39 and, **B** species, on the same axes.

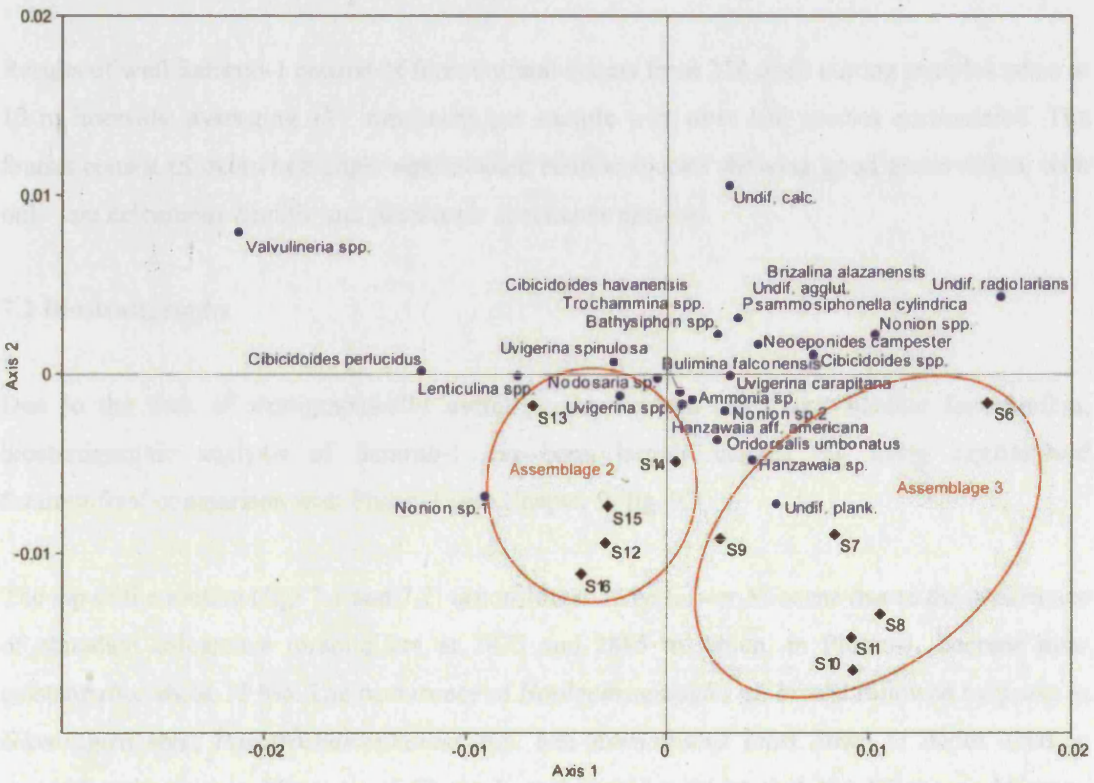


Figure 6.9 Results of Correspondence Analysis for samples S6 – S16 only (Assemblages 2 and 3), and species with > 3 occurrence per sample. Circles encompass samples from the same assemblage.

CHAPTER 7 – RESULTS WELL SATURNO-1

Results of well Saturno-1 consist of foraminiferal counts from 214 ditch cutting samples taken at 10 m intervals, averaging 117 specimens per sample with over 130 species encountered. The faunas consist of overwhelmingly agglutinated benthic species showing good preservation, with only rare calcareous benthic and planktonic specimens present.

7.1 Biostratigraphy

Due to the lack of stratigraphically useful planktonic and calcareous benthic foraminifera, biostratigraphic analysis of Saturno-1 has been largely carried out using agglutinated foraminiferal comparison with Plutao-1 (see Chapter 9, fig. 9.1).

The top of the section (figs 7.1 and 7.2) is considered to be Lower Miocene due to the occurrence of abundant calcareous foraminifera at 2875 and 2885 m which, in Plutao-1, become non-existent after about 18 Ma. The occurrence of *Haplophragmoides* cf. *bradyi* followed by peaks in *Glomospira* spp., *Paratrochamminoides* spp. and *Ammodiscus latus* down to depth 3300 m resembles the Lower Miocene of Plutao-1, and would suggest that the Oligocene-Miocene boundary is somewhere around 3200 m.

Low abundance and diversity down to 3500 m, due to the sandy submarine channel deposits, obscures biostratigraphical analysis. This section probably contains the Oligocene-Miocene boundary as the high diversity faunas from 3580 m resemble similar faunas in Plutao-1 that occur well into the Oligocene. The prominent *Scherochorella congoensis* event at around 3760 m is also observed in Plutao-1 at intra-Upper Oligocene.

The base of the well contains predominantly *Nothia robusta* and *Trochammina* spp., as well as persistent *Reticulophragmium rotundidorsatum* and *R. acutidorsatum* which are comparable to assemblages at the base of the Upper Oligocene in Plutao-1. This suggests that the Upper Oligocene – Middle Eocene unconformity has not yet been reached in this well, and that all samples down to 5000 m are Upper Oligocene.

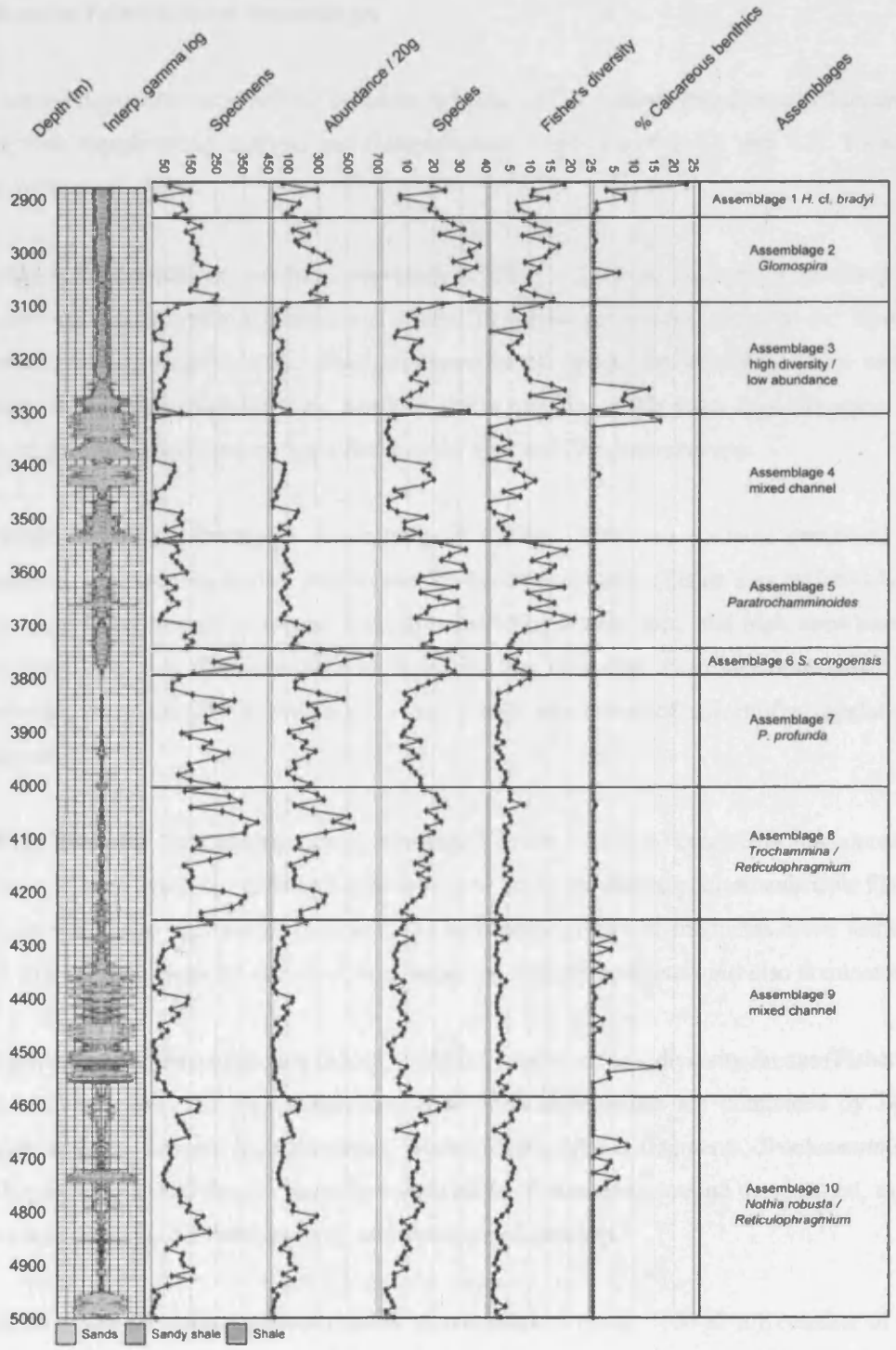


Figure 7.1. Graphs of abundance and diversity against depth, gamma log and interpreted assemblages for Saturno-1. Abundance given as raw counts and absolute abundance, diversity given as number of species and Fisher's (αx). Percentage of calcareous fauna is also shown.

7.2 Benthic Foraminiferal Assemblages

Ten assemblages have been defined based on foraminiferal abundance and diversity fluctuations, along with morphogroup analysis and Correspondence Analysis (figs 7.1 and 7.2). These are, from youngest to oldest:

(1) *Haplophragmoides* cf. *bradyi* Assemblage 1 (2875 – 2930 m) consists of relatively high diversity and high abundance faunas, with around 20 species per sample (Fisher's αx = 10 to 20). Abundant tubular fragments and *Haplophragmoides* cf. *bradyi* are common. Some samples contain several calcareous benthics, some as pyrite moulds, which show high diversity. Also contains persistent *Saccammina* spp., *Recurvoides* spp. and *Trochammina* spp.

(2) High diversity *Glomospira* Assemblage 2 (2940 – 3090 m) contains continued high abundances and diversity faunas, with around 30 species per sample (Fisher's αx = 10 to 15). The assemblage is dominated by tubular fragments including *Nothia* spp., and high abundances of *Glomospira* spp. and *Saccammina* spp. Also contains persistent *Paratrochamminoides* spp., *Recurvoides* spp. and *Trochammina* sp. 1 and a high proportion of unidentified agglutinated fragments.

(3) High diversity / low abundance Assemblage 3 (3100 – 3300 m) consists of low abundance faunas with high diversity. Although species counts are lower due to poor abundances, Fisher's αx shows continued high values (5 to 20). The percentage of tubular fragments drops markedly, but is still common, with the species *Saccammina* spp. and *Ammodiscus latus* also dominating.

(4) Mixed channel Assemblage 4 (3310 – 3540 m) consists of low diversity faunas (Fisher's αx = 5) with both low and high abundance. High abundance faunas are dominated by *Nothia robusta*, and both low and high abundance faunas contain tubular fragments, *Trochammina* spp. and *Haplophragmoides bradyi*. Rare *Textularia earlandi* also occur around this interval, as well as *Recurvoides* spp., *Saccammina* spp., and *Psammosphaera* spp.

(5) High diversity *Paratrochamminoides* Assemblage 5 (3550 – 3740 m) consists of high diversity (Fisher's αx = 10 to 15) and high abundance faunas, exhibiting a wide spread of species occurrences that are not dominated by individual taxa. Common species include tubular fragments of *Rhabdammina* spp., *Rhizamina* spp., *Bathysiphon* app., and *Nothia* spp., along with

several species of *Paratrochamminoides* spp., *Trochammina* spp., *Ammodiscus latus*, *Recurvoides* spp. and *Reophax pilulifer.*

(6) *Scherochorella congoensis* Assemblage 6 (3750 – 3790 m) consists of a small interval (40 m) dominated by the species *Scherochorella congoensis* (up to 50 % of the fauna). Other dominant species include tubular fragments, *Trochammina* spp., *Nothia robusta*, *Portatrochammina profunda* and *Discamminoides* sp. 1. Abundance is extremely high, and diversity shows a small decrease from the assemblage above although still high (Fisher's $\alpha x = 5$ to 10).

(7) *Portatrochammina profunda* Assemblage 7 (3800 – 4000 m) consists of very low diversity (Fisher's $\alpha x < 5$) and very high abundance faunas, dominated by the species *Portatrochammina profunda*, *Nothia robusta* and *Trochammina* spp. This assemblage represents the most highly dominated section of the well, with the three mentioned taxa typically making up over 95 % of the fauna.

(8) *Trochammina / Reticulophragmium* Assemblage 8 (4010 – 4260 m) consists of low diversity (Fisher's $\alpha x = 5$) and high abundance faunas that are dominated by small *Trochammina* spp. Species of *Reticulophragmium* spp. are common, as are tubular fragments, *Saccammina* spp., *Ammodiscus* spp. and *Portatrochammina profunda.* The small nature of the dominant *Trochammina* hampers identification, and there is the possibility that these are simply juvenile *Portatrochammina profunda.*

(9) Mixed channel Assemblage 9 (4270 – 4580 m) consists of low diversity faunas (Fisher's $\alpha x < 5$) with both low and high abundance. High abundance faunas are dominated by tubular fragments of *Nothia robusta*, *Rhabdammina* spp. and *Nothia* spp., along with small *Trochammina* spp. and *Portatrochammina profunda.* Many of the samples contain a few badly preserved and probably transported small calcareous specimens.

(10) *Nothia robusta / Reticulophragmium* Assemblage 10 (4590 – 5000 m) contain predominantly low diversity (Fisher's $\alpha x = 5$) but high abundance faunas dominated by the species *Trochammina* spp. and *Nothia robusta.* Also present are other tubular fragments, and specimens of *Reticulophragmium* spp., *Recurvoides* spp., *Saccammina* spp., and poorly preserved calcareous tests that have probably been transported.

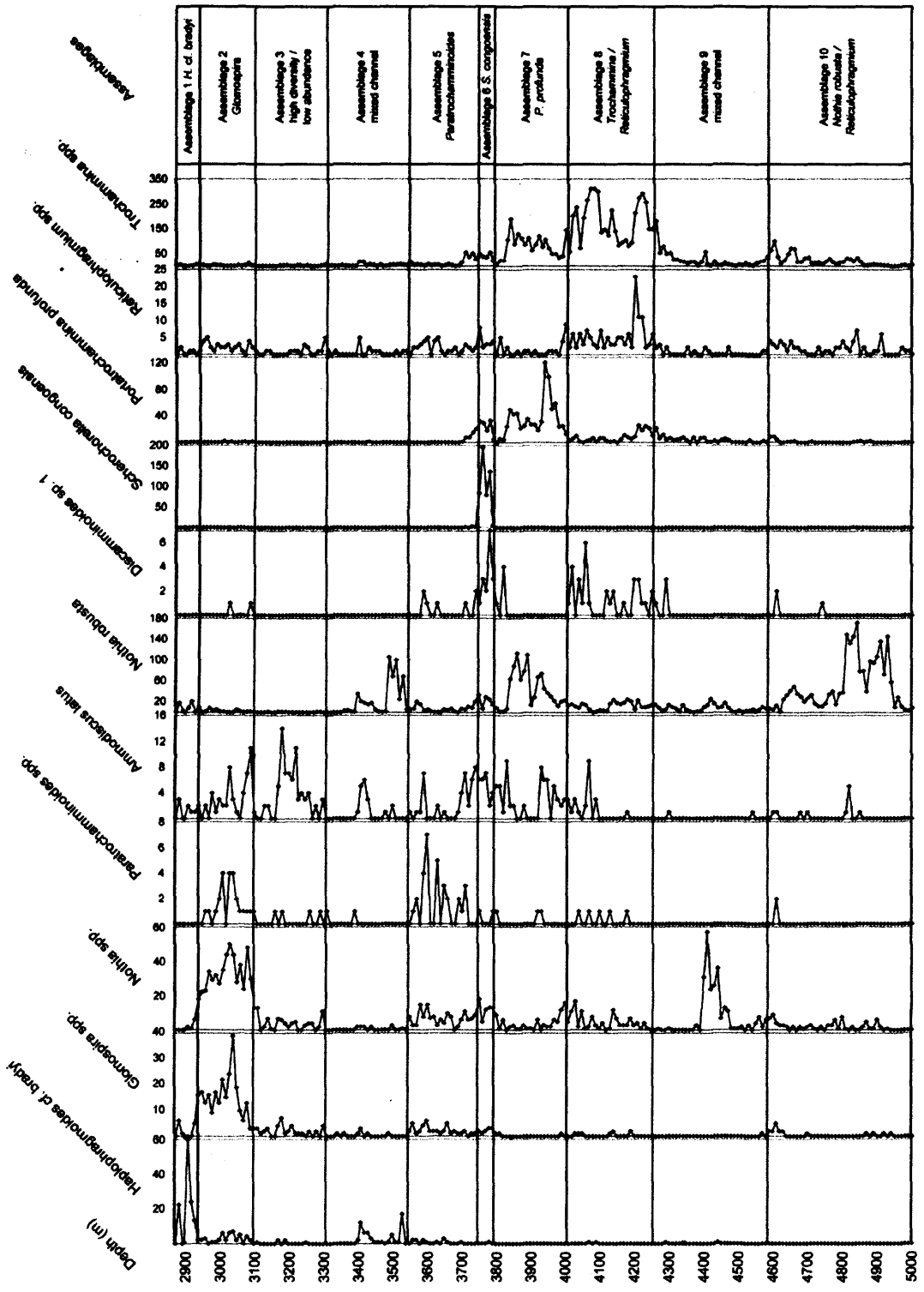


Figure 7.2. Graphs of selected species abundances against depth and interpreted assemblages for Saturno-1. Data represents raw species counts.

7.3 Correspondence Analysis Results

Correspondence Analysis (CA) carried out on the entire data set (fig. 7.3) reveals the clustering of samples around those species which are dominant in those samples, and adds statistical support to the assemblages defined for this well. The analysis has been carried out on the agglutinated foraminifera only as these by far dominate the well and the few calcareous species present have been largely interpreted as transported. The CA of species (fig. 7.3a) shows that the majority of species encountered cluster around the origin, and therefore show no particular 'preference' for depth horizons and/or exhibit very low abundance. Species deviating from the origin by a significant amount do show clustering around certain depths, and high abundance, and are therefore the most important species when looking for palaeoecological indicators. The species *P. profunda* and *Trochammina* spp. have the lowest axis 1 values and occupy a similar area on the graph, *N. robusta* has the lowest axis 2 values and low axis 1 values, *S. congoensis* shows extreme positive axis 2 values, and *G. gordialis*, *Nothia* spp., and *Rhabdammina* spp. have the highest axis 1 values. The separation of these groups of species suggests they are responding differently to palaeoecological factors.

The CA of assemblages (fig. 7.3b) shows all sample depths on the same axes as the species, the data points having been converted to symbols indicating which assemblage they belong to. The general clustering of samples from each assemblage indicates that samples from these assemblages do indeed show statistical similarity. Assemblages close together show more similarity, in terms of their species compositions, to one another than assemblages occupying a different space, and the further away from the origin each sample is, the more defined the assemblage is. Assemblage 6 is dominated by *S. congoensis* and this is clearly shown. Assemblages 7 and 8 correlate well with *P. profunda* and *Trochammina* spp. respectively, which indicates that they may be responding to similar ecological factors in a similar way. Assemblage 10 shows clear proximity to *N. robusta*. The species *R. rotundidorsatum* is slightly closer to these assemblages, therefore demonstrating loose affinities with all three. Assemblage 2 is also clearly defined in the analysis, and is positioned close to *Glomospira* spp. as well as *Nothia* spp., *Bathysiphon* spp. and *H.* cf. *bradyi*. Assemblage 1 also exhibits a close position to *H.* cf. *bradyi*. Assemblages 3 and 5, with their definition of high diversity and a more even spread of species, understandably occur close to the origin along with the majority of species. The result is the same for Assemblages 4 and 9, but in this case it is because of their low abundance.

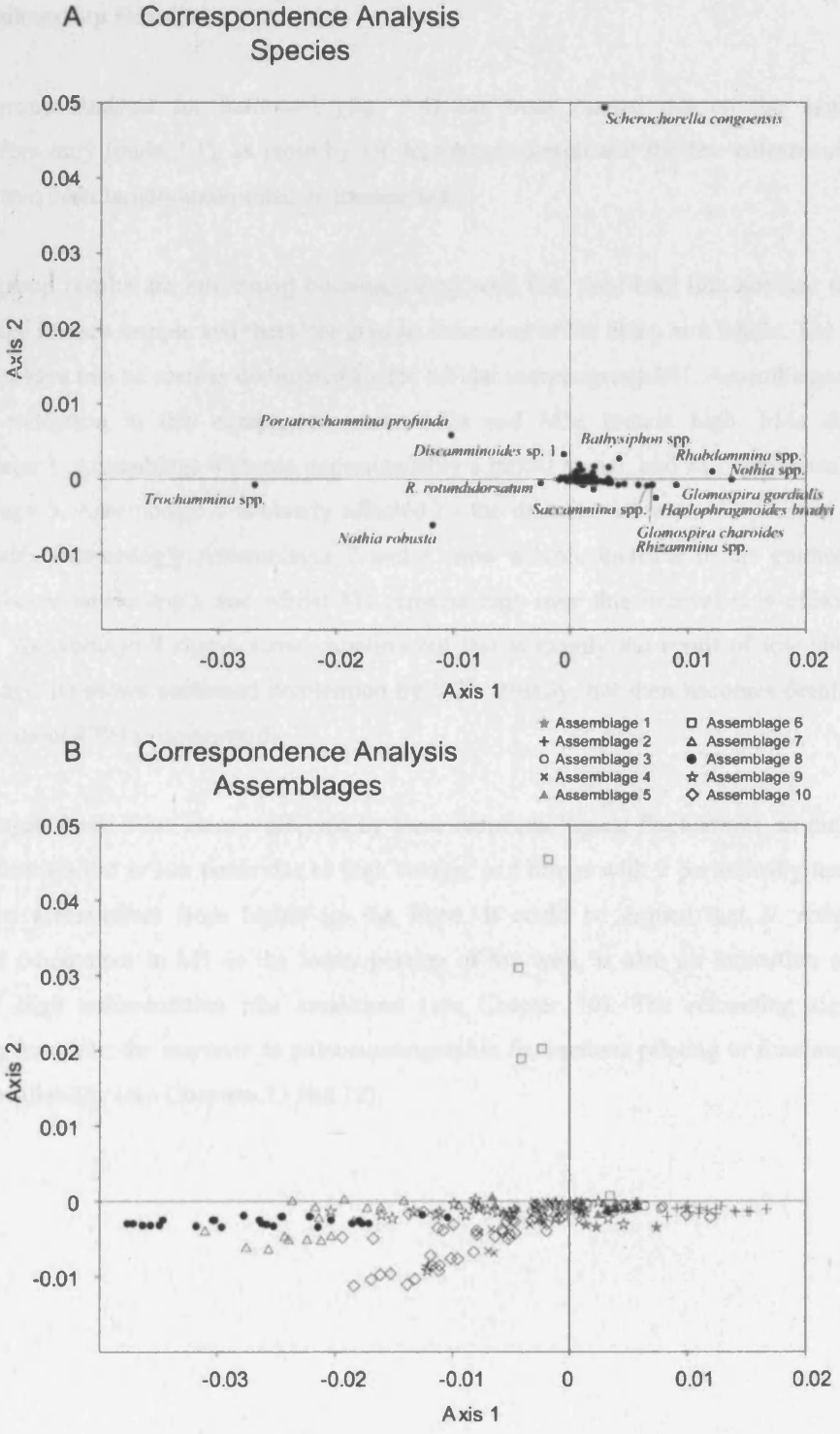


Figure 7.3. Results of Correspondence Analysis for Saturno-1, including **A** all species, and **B** all samples. Sample depths have been converted to symbols referring to assemblage affinity.

7.4 Morphogroup Results

Morphogroup analysis for Saturno-1 (fig. 7.4) has been carried out on the agglutinated foraminifera only (table 7.1), as these by far dominate the well and the few calcareous species present have been largely interpreted as transported.

Morphogroup results are interesting because, along with CA, they take into account the entire assemblage in each sample and therefore give an indication of the fauna as a whole. The majority of assemblages can be seen as dominated by the tubular morphogroup M1. Assemblages 1 and 3 show a reduction in this component whilst M2a and M3a remain high. M4a dominates Assemblage 1. Assemblage 4 shows understandably a mixed signal, and M1 dominates again in Assemblage 5. Assemblage 6 is clearly affected by the dramatic increase in epifaunal M4b (*S. congoensis*). Interestingly Assemblages 7 and 8 show a large increase in the epifaunal M2b group (*Trochammina* spp.), and whilst M1 remains high over this interval it is offset by this increase. Assemblage 9 shows some variation but this is mainly the result of low abundance. Assemblage 10 shows continued domination by M2b initially, but then becomes dominated by M1 from about 4700 m downwards.

Assemblages 4 and 9 are clearly affected by local sedimentological fluctuations, as the channel system destroys the *in situ* fauna due to high energy, and brings with it periodically transported calcareous foraminifera from higher up the slope. It could be argued that *N. robusta*, the dominant component in M1 in the lower portion of the well, is also an indication of higher energy / high sedimentation rate conditions (see Chapter 10). The remaining signals are probably, however, the response to palaeoceanographic fluctuations relating to food supply and oxygen availability (see Chapters 11 and 12).

Erect epifauna M1

Bathysiphon spp.
Hyperammina elongata
Hyperammina spp.
Nothia robusta
Nothia spp.
Psammosiphonella cylindrica
Rhabdammina linearis
Rhabdammina spp..
Rhizammina spp.
Tolypammina spp.

Shallow infauna globular M2a

Aschemocella grandis
Hormosina globulifera
Placentammina placenta
Praesphaerammina spp.
Psammosphaera sp. 2
Psammosphaera spp.
Reophanus berggreni
Reophax pilulifer
Saccammina spp.

Surficial epifauna trochospiral M2b

Buzasina pacifica
Caudammina ovuloides
Conglophragmium irregularis
Cribrostomoides sp. 1
Cribrostomoides subglobosus
Lituotuba lituiformis
Paratrochamminoides aff. *deflexiformis*
Paratrochamminoides gorayskiformis
Paratrochamminoides gorayskii
Paratrochamminoides olszewskii
Paratrochamminoides sp. 1
Paratrochamminoides spp.
Portatrochammina profunda
Recurvoides azuaensis
Recurvoides sp. 1
Recurvoides spp.
Trochammina sp. 1
Trochammina sp. 2
Trochammina spp.
Trochamminoides challengeri
Trochamminoides spp.
Trochamminoides subcoronatus

Surficial epifauna keeled M2c

Gaudryina atlantica

Surficial epifauna flattened M3a

Ammodiscus aff. *peruvianus*
Ammodiscus cretaceus
Ammodiscus glabratus
Ammodiscus latus
Ammodiscus sp. 1
Ammodiscus spp.
Ammodiscus tenuissimus
Ammosphaeroidina pseudopauciloculata
Glomospira aff. *serpens*
Glomospira aff. *serpens*
Glomospira charoides
Glomospira glomerata
Glomospira gordialis
Glomospira irregularis
Glomospira sp. 1
Glomospira sp. 2
Glomospira spp.
Spiropsammina primula

Surficial epifauna irregular M3b

Ammolagena clavata
Discamminoides sp.1

Shallow infauna planispiral M4a

Ammomarginulina spp.
Budashevaella multicamerata
Cyclammina spp.
Glaphyrammina americana
Haplophragmoides bradyi
Haplophragmoides carinatus
Haplophragmoides horridus
Haplophragmoides nauticus
Haplophragmoides sp. 1
Haplophragmoides sp. 2
Haplophragmoides spp.
Haplophragmoides walteri
Reticulophragmium acutidorsatum
Reticulophragmium amplectens
Reticulophragmium gasparensis
Reticulophragmium intermedium
Reticulophragmium orbicularis
Reticulophragmium rotundidorsatum
Reticulophragmium sp. 1
Reticulophragmium sp. 2
Reticulophragmium spp.
Reticulophragmium venezuelanum

Deep infauna M4b

Dorothia brevis
Eggerella bradyi
Eggerelloides sp. 1
Hormosina glabra
Hormosinelloides guttifer
Kalamopsis spp.
Karrerulina apicularis
Karrerulina coniformis
Karrerulina conversa
Karrerulina spp.
Pseudonodosinella elongata
Pseudonodosinella nodulosa
Reophax duplex
Reophax pyrifer
Reophax sp. 2
Reophax spp.
Scherochorella congoensis
Subreophax pseudoscalaris
Subreophax scalaris
Subreophax spp.
Textularia earlandi
Textularia spp.
Valvulina flexilis
Verneuilina sp. 1

Table 7.1. List of agglutinated species placed within each morphogroup followed in this study (Van den Akker et al. 2000).

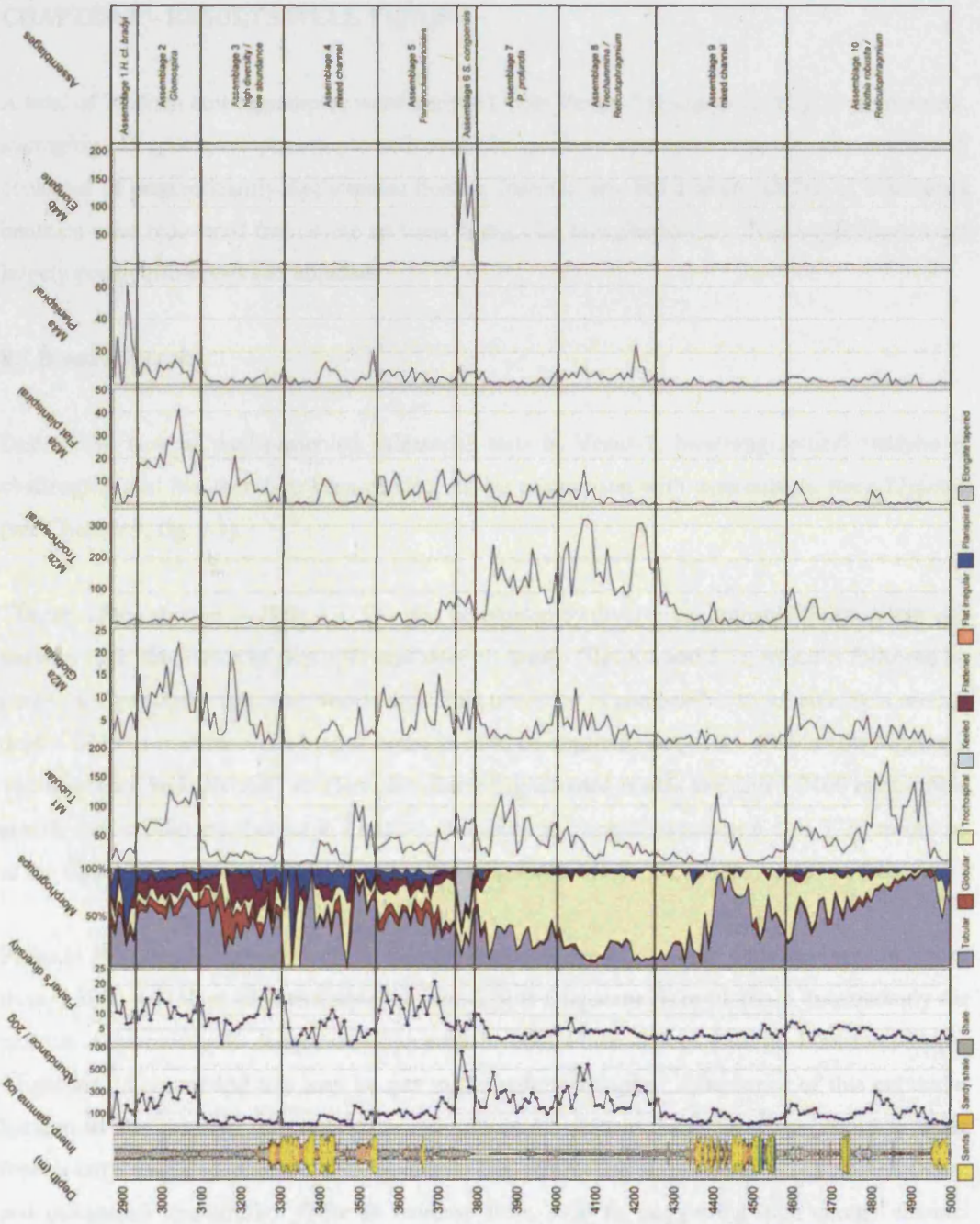


Fig. 7.4. Morphogroups of agglutinated benthic foraminifera against depth, gamma and interpreted assemblages for Saturno-1. Morphogroups given both as a percentage of total fauna, and as absolute counts. Abundance and diversity also shown.

CHAPTER 8 – RESULTS WELL VENUS-1

A total of 72 ditch cutting samples were analysed from Venus-1 at approximately 20 m intervals, averaging 119 specimens per sample with over 135 species encountered. The majority of the well consisted of predominantly agglutinated benthic foraminifera, but a large number of calcareous benthics were recovered from some sections along with rare planktonics. These specimens were largely poorly preserved and abraded.

8.1 Biostratigraphy

Due to the lack of well-preserved calcareous tests in Venus-1, biostratigraphical analysis is challenging and has therefore been carried out by comparison with assemblages from Plutao-1 (see Chapter 9, fig. 9.1).

The top of the section (~ 3100 – 3150 m) is dominated by diverse agglutinated foraminifera and shows a high abundance of *Haplophragmoides* cf. *bradyi* (figs 8.1 and 8.2), which is followed by peaks in *Glomospira* spp. and *Nothia* spp. This transition is comparable to assemblages around depths 3250 m in Plutao-1, which is considered to be approximately 18 – 19 Ma (Burdigalian). The following high diversity and low abundance agglutinated faunas to depth ~ 3400 m resemble similar Lower Miocene faunas in Plutao-1. The peak in *Textularia earlandi* at ~ 3720 m occurs in the Upper Oligocene in Plutao-1, and so the Oligocene-Miocene boundary is above this.

Peaks in *Portatrochammina profunda* and *Discamminoides* sp. 1, along with increased diversity from ~ 3820 – 4130 m, also resemble the intra-Upper Oligocene from Plutao-1. Interestingly the peak in *Scherochorella congoensis*, apparent in both Plutao-1 and Saturno-1 as intra-Upper Oligocene, is absent and this may be due to the sedimentological disturbance of this particular horizon in this location (the interval is only about 40 – 50 m thick). Analysis of all samples reveals not a single specimen of *S. congoensis*. The gamma log shows numerous sandy horizons, and calcareous foraminifera show an increase from 3950 m, suggesting high energy channel deposition.

The base of the well exhibits poor foraminiferal recovery, and is dominated by poorly preserved (and probably transported) calcareous tests. This section is therefore ambiguous in age and a determination has not been made. However the persistently occurring *Reticulophragmium* spp. and *Discamminoides* sp. 1 does resemble the base part of Plutao-1 (Upper Oligocene).

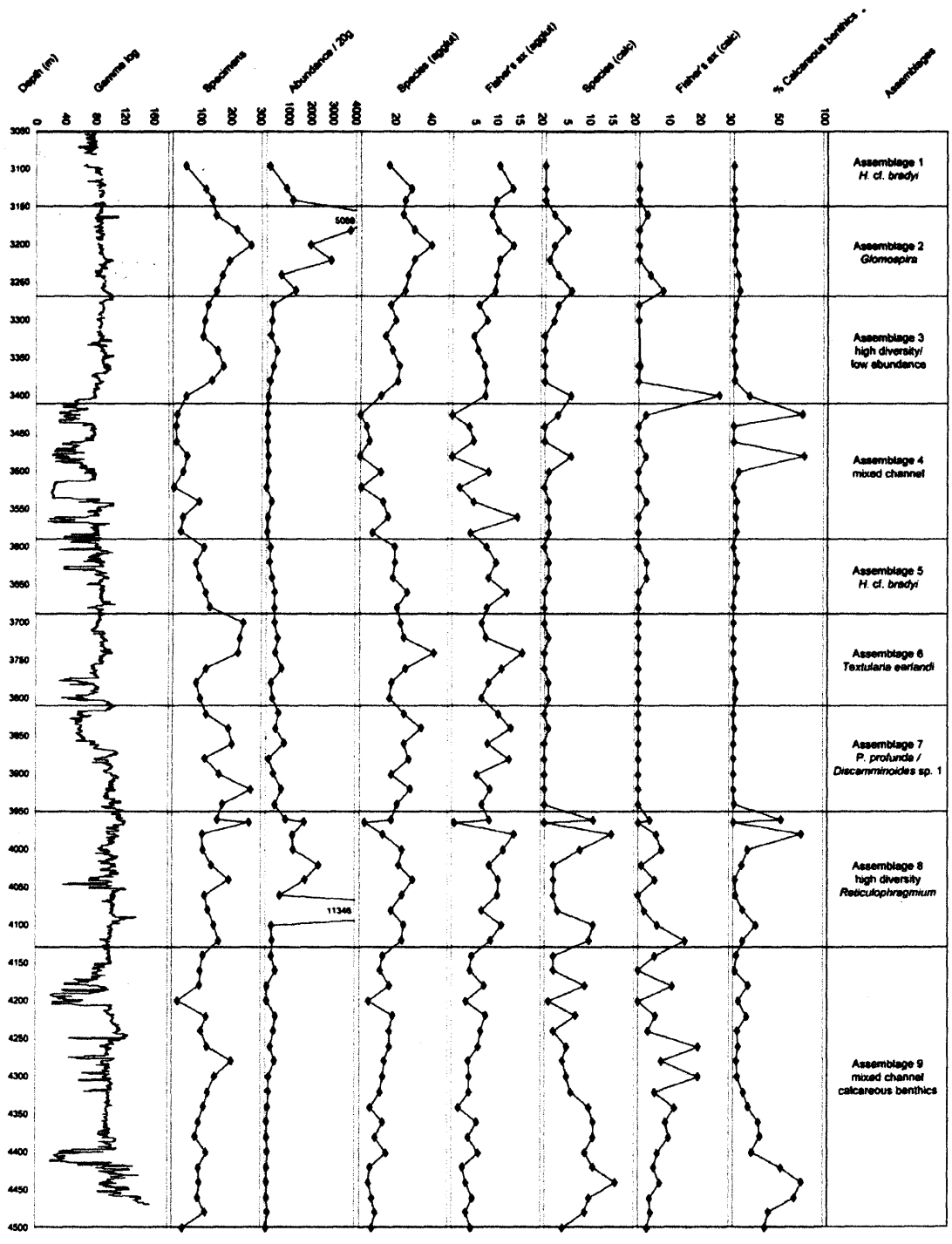


Figure 8.1 Graphs of abundance and diversity against depth, gamma log and interpreted assemblage for Venus-1. Abundance is given in raw counts and in absolute abundance. Diversity is given as number of species and Fisher's (αx) for both agglutinated and calcareous foraminifera. Percentage of calcareous foraminifera is also shown.

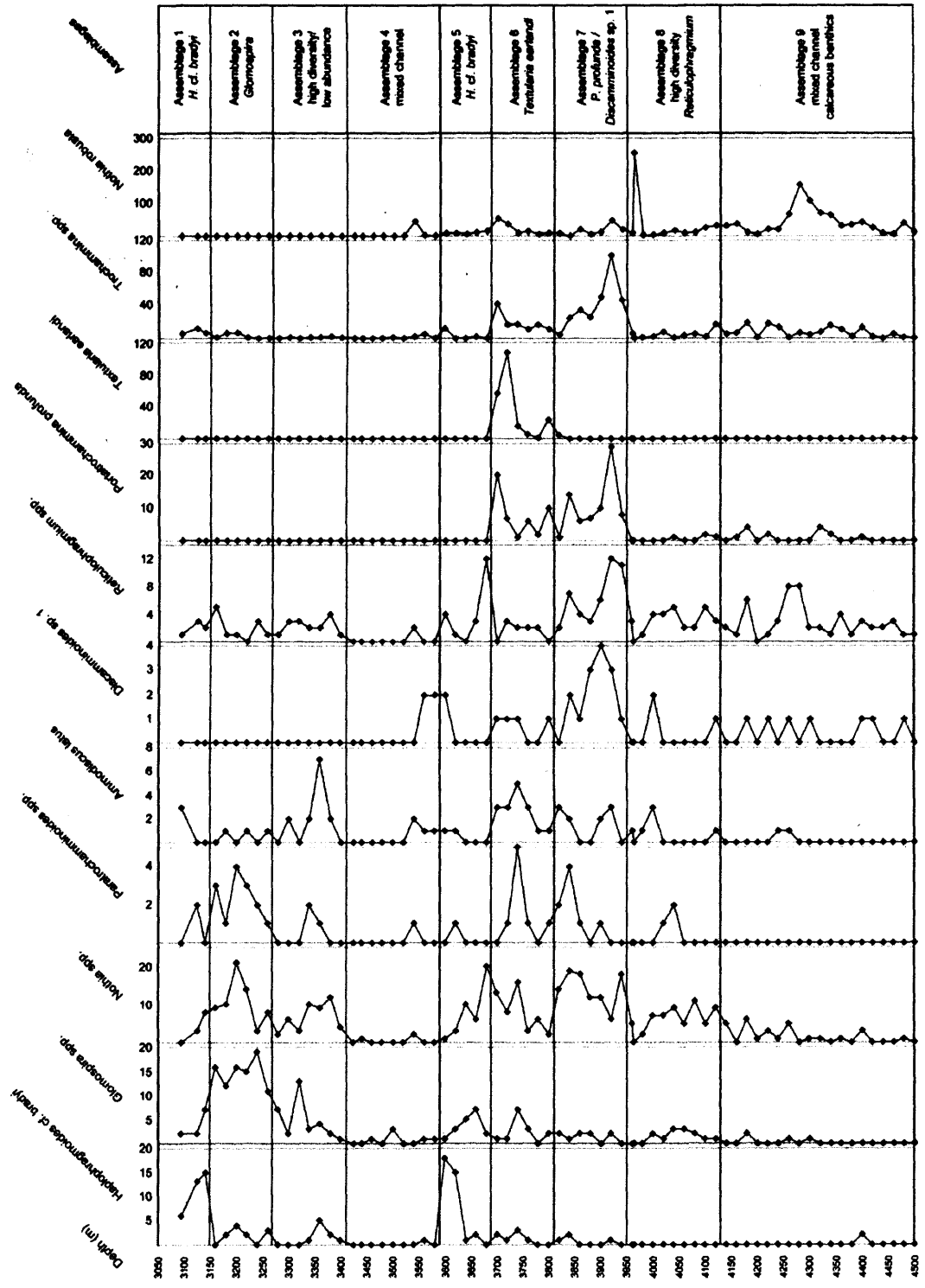


Figure 8.2 Graphs of selected species abundances against depth and interpreted assemblages for Venus-1. Data represents raw species counts.

8.2 Benthic Foraminiferal Assemblages

Nine assemblages have been defined for Venus-1 (figs 8.1 and 8.2) based on foraminiferal species abundance and diversity variations, morphogroup analysis, and Correspondence Analysis, and are listed from youngest to oldest:

(1) *Haplophragmoides* cf. *bradyi* Assemblage 1 (3100 – 3140 m) consists of relatively high diversity and high abundance faunas, with around 25 species per sample (Fisher's αx = 10 to 15). Abundant tubular fragments and *Haplophragmoides* cf. *bradyi* are common. Also contains persistent *Saccammina* spp., *Recurvoides* spp. and *Trochammina* spp., as well as *Budashevaella multicamerata* and *Cribrostomoides subglobosus.* Samples are entirely agglutinated in nature.

(2) High diversity *Glomospira* Assemblage 2 (3160 – 3260 m) contains continued high abundance and diversity faunas, with around 30 species per sample (Fisher's αx = 10). The assemblage is dominated by tubular fragments including *Nothia* spp., and high abundances of *Glomospira* spp. and *Saccammina* spp. Also contains persistent *Paratrochamminoides* spp., *Ammodiscus* spp., *Recurvoides* spp. and *Trochammina* sp. 1 and a high proportion of unidentified agglutinated fragments. Calcareous benthics make up a small fraction of this assemblage. Abundance per gram can be extremely high (fig. 8.1), but this is probably the result of low sand content.

(3) High diversity / low abundance Assemblage 3 (3280 – 3400 m) consists of lower abundance faunas with continued high diversity (Fisher's αx = 7). The percentage of tubular fragments increases to about 75 %, with the species *Saccammina* spp., *Ammodiscus latus* and *Glomospira charoides* persistently occurring. Calcareous benthics make up a small fraction of this assemblage.

(4) Mixed channel Assemblage 4 (3420 – 3580 m) consists of generally low abundance and diversity faunas (Fisher's αx = 5), and some high abundance samples dominated by *Nothia robusta* and *Nonion* spp. Other tubular fragments of *Rhizammina* spp. and *Rhabdammina* spp. are also common.

(5) *Haplophragmoides* cf. *bradyi* Assemblage 5 (3600 – 3680 m) consists of relatively high diversity and high abundance faunas, with around 20 species per sample (Fisher's αx = 10). Abundant tubular fragments and *Haplophragmoides* cf. *bradyi* are common. Also contains

persistent *Saccammina* spp., *Recurvoides* spp., *Trochammina* spp. and *Ammosphaeroidina pseudopauciloculata.*

(6) *Textularia earlandi* Assemblage 6 (3700 – 3800 m) consists of an interval sporadically dominated by the species *Textularia earlandi* (up to 50 % of the fauna). Other dominant species include tubular fragments, *Nothia robusta, Trochammina* spp. and *Portatrochammina profunda.* Abundance is high, and diversity can be extremely high (Fisher's αx = 7 to 15) with over 40 agglutinated species present in one sample.

(7) *Portatrochammina profunda / Discamminoides* Assemblage 7 (3820 – 3940 m) consists of relatively high abundance and diversity faunas (Fisher's αx = 10 to 15) dominated by *Trochammina* spp. and *Portatrochammina profunda,* and tubular fragments of *Rhabdammina* spp., *Nothia* spp. and *Nothia robusta.* Other persistent species include *Recurvoides* spp. and *Saccammina* spp.

(8) High diversity *Reticulophragmium* Assemblage 8 (3960 – 4120 m) consists of high diversity (Fisher's αx = 10) and sporadically extremely high abundance faunas containing up to 60 % poorly-preserved calcareous benthics. Tubular fragments dominate agglutinated faunas, along with *Recurvoides* spp., *Saccammina* spp. and *Nothia robusta. Reticulophragmium* spp. is also a persistent component. The most commonly occurring calcareous species are *Cibicidoides* spp., *Uvigerina carapitana* and *Bulimina* spp. Diversity is high largely due to the addition of a calcareous fauna, although agglutinated diversity here is equal to the highest for the entire well. High abundance is probably partly due to reduced sand content.

(9) Mixed channel Assemblage 9 (4140 – 4500 m) consists of decreased and decreasing diversity (Fisher's αx = 5) and abundance, and an increasingly dominant calcareous content which is frequently poorly preserved. Agglutinated foraminifera are dominated by *Nothia robusta,* and show a persistence in *Reticulophragmium* spp. Species of *Uvigerina* spp. and *Bulimina* spp. make up the majority of the calcareous fauna.

8.3 Correspondence Analysis Results

Correspondence Analysis (CA) for the entire data set (fig. 8.3) shows the clustering of samples around those species which are dominant in those samples, and adds statistical support to the assemblages defined in this well. For the purposes of this analysis, all calcareous foraminifera

have been lumped together since they are interpreted as transported (over this section) and thus represent a single ecological signal. The CA of species (fig. 8.3a) reveals that the majority of species cluster around the origin, and therefore show only a weak 'preference' for depths and/or exhibit very low abundance. Species deviating from the origin by a significant amount show high abundance and clustering around certain depths, and are therefore the most important species when looking for palaeoecological indicators. The species *T. earlandi*, and to a lesser extent *Trochammina* spp. and *P. profunda*, has low axis 2 values. *Nothia robusta* occupies the most negative axis 2 and positive axis 1 values, whilst 'total calcareous foraminifera' (TCF) has the most extreme positive axis 1 and positive axis 2 values. 'Total undifferentiated agglutinates' (TUA) are grouped with *Rhabdammina* spp. and *Rhizammina* spp. with negative axis 1 values, along with, to a lesser extent, *H.* cf.. *bradyi*, *G. gordialis*, *G. charoides*, *Bathysiphon* spp. and *Nothia* spp. On the right hand side of the central clump are species of *Reticulophragmium* spp., and at the bottom are *A. pseudopauciloculata*, *A. latus* and *Discamminoides* sp.1. The separation of these groups of species suggests they are responding differently to palaeoecological factors.

The CA of assemblages (fig. 8.3b) shows all sample depths on the same axes as the species, the data points having been converted to symbols indicating which assemblage they belong to. The general clustering of samples within most assemblages (though not all) indicates that samples from these assemblages do indeed show statistical similarity. Assemblages close together show more similarity to one another, in terms of their species compositions, than assemblages occupying a different space, and the further away from the origin each sample is, the more defined the assemblage is. Assemblages 1 and 5 are clustered close together near *H.* cf. *bradyi* as this species is common to both. Assemblages 2 and 3 are also indistinguishable from each other in this analysis and occupy the most negative axis 1 values, close to *Glomospira* spp., *Rhizammina* spp., *Rhabdammina* spp., *Bahysiphon* spp., and TUA, which these samples all have in common. Assemblage 4 is largely clustered around the origin (suggesting no characteristic fauna, or very low abundance) with some samples occupying positive axis 1 and axis 2 values towards TCF. This assemblage is defined as 'mixed channel' and therefore can be expected occasionally to contain some reworked calcareous foraminifera. Assemblage 6 shows some clustering around the species *T. earlandi*, and Assemblage 7 shows proximity to the characteristic species *Discamminoides* sp.1 and *P. profunda*. Assemblage 8 shows a rather wide spread of points, with some clearly affected by TCF and others more towards the central cluster of species (indicating high diversity). Assemblage 9 shows the strongest influence from the species *N. robusta* and TCF, which characterise these faunas.

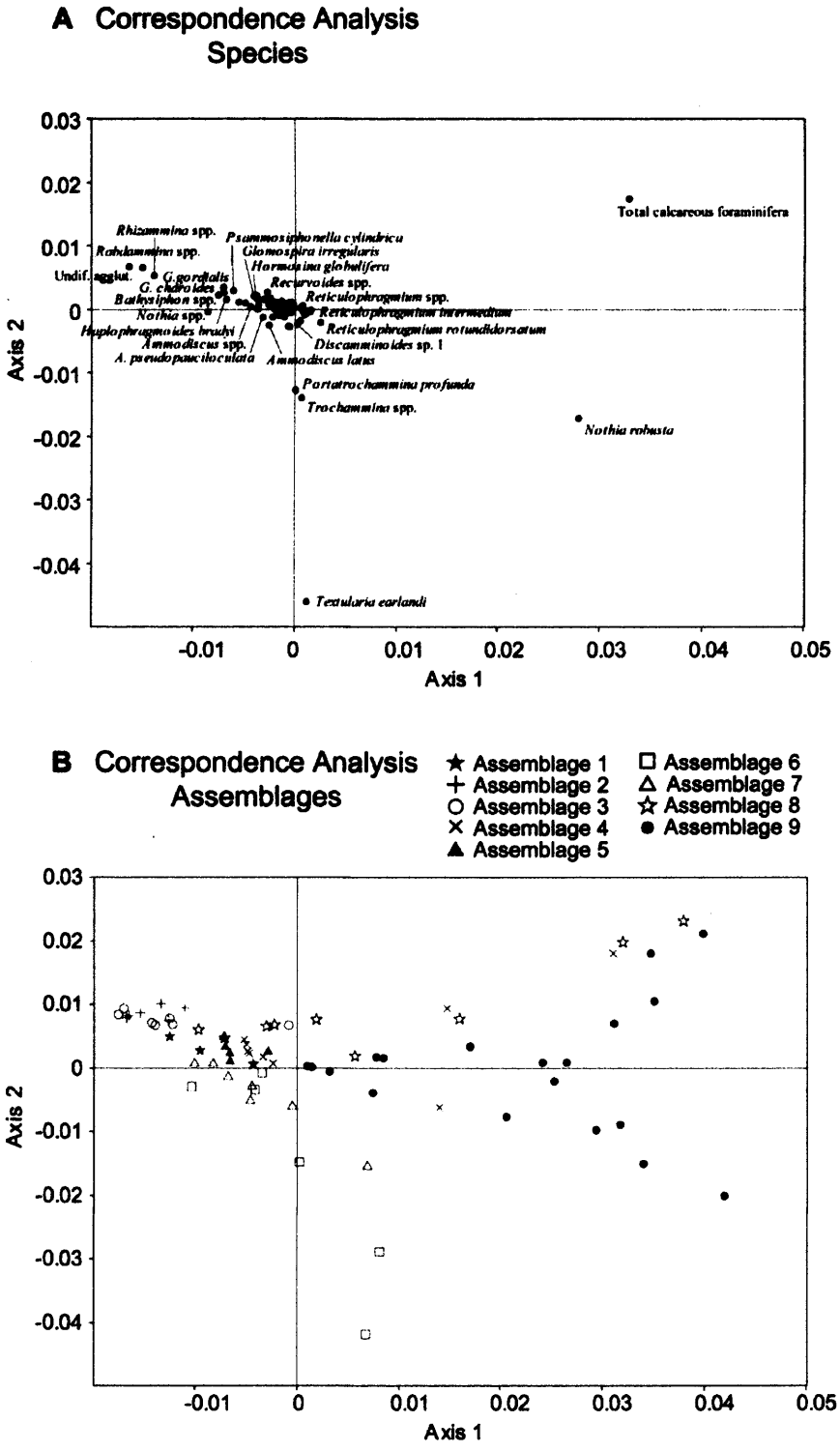


Figure 8.3 Results of Correspondence Analysis for Venus-1, including **A** all species, and **B** all samples. Sample depths have been converted to symbols referring to assemblage affinity.

8.4 Morphogroup Results

Morphogroup analysis for Saturno-1 (fig. 8.4) has been carried out on agglutinated foraminifera only (table 8.1) since this component dominates the well and is interpreted as a largely *in situ* fauna. The calcareous species present here are interpreted as transported.

Morphogroup analyses can give interesting results in that, along with CA, it takes into account the entire assemblage in each sample and therefore gives an indication of the fauna as a whole (although the significant oversimplification in this technique must be appreciated). The majority of assemblages can be seen as dominated by the tubular morphogroup M1. Assemblages 1 and to some extent 5 show a reduction in this component whilst M4a exhibits an increase. Assemblage 2 shows high proportions of M2a and M3a, and Assemblage 3 shows a reduction in these groups but persistently high M1. Assemblage 4 has understandably a mixed signal. Assemblage 6 shows a clear increase in M4b (*T. earlandi*), and Assemblage 7 shows a clear increase in M2b (*Trochammina* spp.). M1 dominates the proportion of morphogroups in Assemblages 8 and 9.

Assemblages 4 and 9 are clearly affected by local sedimentological fluctuations, as the channel system destroys the *in situ* fauna due to high energy conditions, and brings with it periodically transported calcareous foraminifera from higher up the slope. It could be argued that *N. robusta*, the dominant component in M1 in the lower portion of the well, is also an indication of higher energy / high sedimentation rate conditions (see Chapter 10). The remaining signals are probably, however, the response to palaeoceanographic fluctuations relating to food supply and oxygen availability (see Chapters 11 and 12).

Erect epifauna M1

Bathysiphon spp.
Hyperammina elongata
Hyperammina spp.
Nothia robusta
Nothia spp.
Psammosiphonella cylindrica
Rabdammina spp.
Rhizammina spp.
Tolypammina spp.

Shallow infauna globular M2a

Aschemocella grandis
Hormosina globulifera
Placentammina placenta
Praesphaerammina spp.
Psammosphaera spp.
Reophanus berggreni
Reophax pilulifer
Saccammina spp.

Surficial epifauna trochospiral M2b

Conglophragmium irregularis
Cribrostomoides subglobosus
Lituotuba lituiformis
Paratrochamminoides gorayskiformis
Paratrochamminoides gorayskii
Paratrochamminoides mitratus
Paratrochamminoides olszewskii
Paratrochamminoides sp. 1
Paratrochamminoides spp.
Portatrochammina profunda
Recurvoides azuaensis
Recurvoides sp. 1
Recurvoides spp.
Trochammina sp. 1
Trochammina sp. 2
Trochammina spp.
Trochamminoides subcoronatus

Surficial epifauna flattened M3a

Ammodiscus cretaceus
Ammodiscus glabratus
Ammodiscus latus
Ammodiscus peruvianus
Ammodiscus spp.
Ammodiscus tenuissimus
Ammosphaeroidina pseudopauciloculata
Glomospira aff. *serpens*
Glomospira charoides
Glomospira gordialis
Glomospira irregularis
Glomospira sp. 1
Glomospira spp
Spiropsammina primula

Surficial epifauna irregular M3b

Ammolagena clavata
Discamminoides sp.1
Discamminoides spp.

Shallow infauna planispiral M4a

Budashevaella multicamerata
Cyclammina cancellata ssp. 1
Cyclammina sp. 1
Cyclammina spp.
Glaphyrammina americana
Haplophragmoides bradyi
Haplophragmoides carinatus
Haplophragmoides horridus
Haplophragmoides nauticus
Haplophragmoides sp. 1
Haplophragmoides spp.
Haplophragmoides walteri
Reticulophragmium acutidorsatum
Reticulophragmium aff. *amplectens*
Reticulophragmium amplectens
Reticulophragmium gasparensis
Reticulophragmium intermedium
Reticulophragmium orbicularis
Reticulophragmium rotundidorsatum
Reticulophragmium sp. 1
Reticulophragmium spp.

Deep infauna M4b

Bigenerina spp.
Eggerella bradyi
Eggerelloides sp. 1
Hormosina glabra
Hormosinelloides guttifer
Kalamopsis spp.
Karreriella bradyi
Karreriella microgranulosa
Karrerulina apicularis
Karrerulina coniformis
Karrerulina spp.
Martinotiella communis
Pseudonodosinella elongata
Reophax spp.
Spiroplectammina spp.
Subreophax scalaris
Subreophax spp.
Textularia earlandi
Valvulina flexilis

Table 8.1. List of agglutinated species placed within each morphogroup followed in this study (Van den Akker et al. 2000).

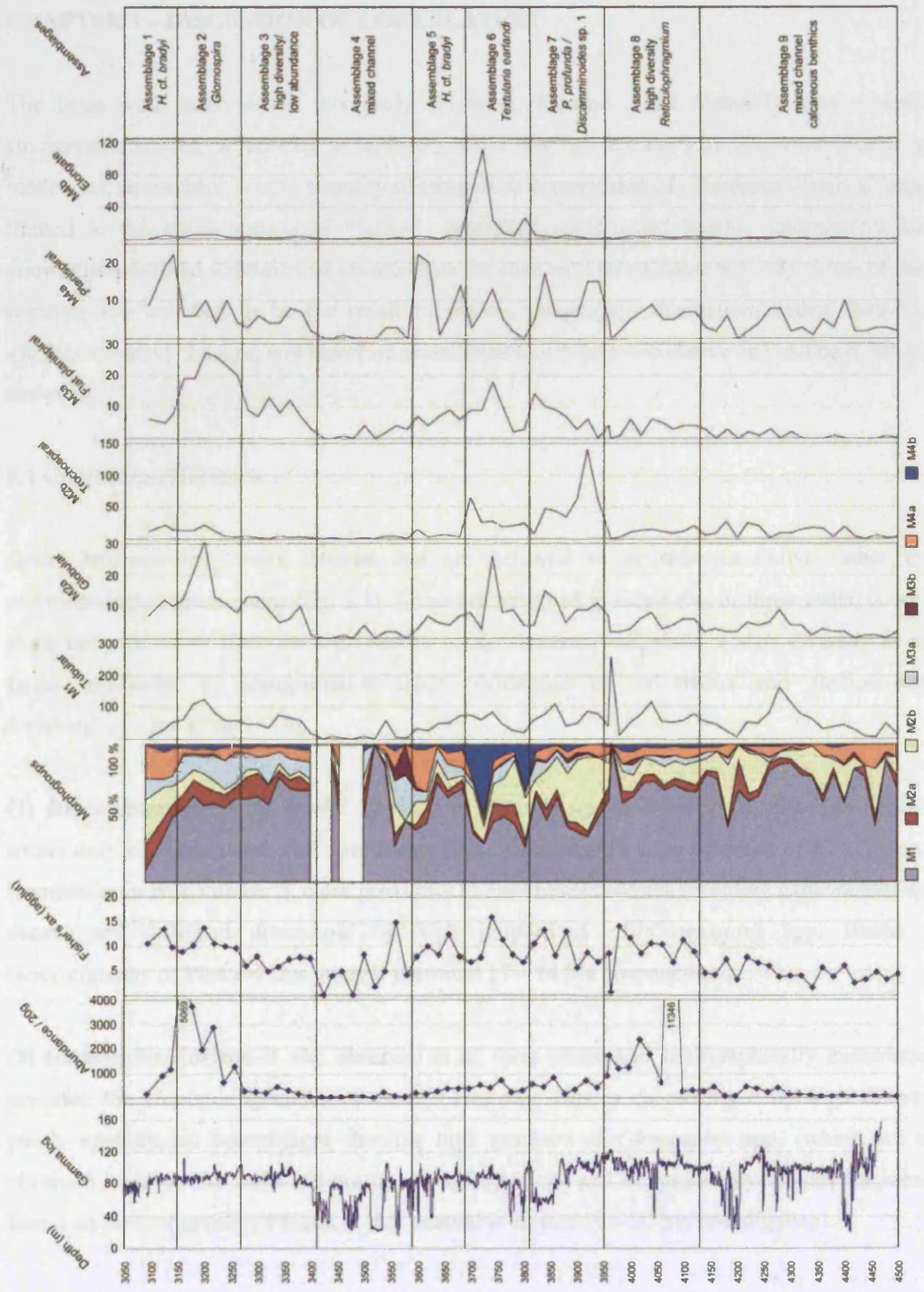


Figure 8.4 Morphogroups of agglutinated benthic foraminifera against depth, gamma and interpreted assemblages for Venus-1. Morphogroups given both as a percentage of the total fauna, and as raw counts. Abundance and diversity is also shown.

CHAPTER 9 – DISCUSSION OF CORRELATION

The three wells analysed in this study (Plutao-1, Saturno-1 and Venus-1) span a similar stratigraphic section as recorded in seismic profiles (see figs 9.2 and 9.3). However, precise age models are unavailable for the majority of samples as preservation of calcareous fossils is largely limited to the upper section of Plutao-1. Abundant agglutinated benthic foraminifera have allowed the detailed definition of assemblages for each well (see Chapters 5 – 8). Some of these horizons are believed to be the result of palaeoceanographic fluctuations rather than local sedimentological changes, and therefore these 'events' are time-correlative and can be used to tie the wells.

9.1 Correlation Horizons

Seven horizons have been defined that are believed to be time-correlative rather than sedimentological phenomena (fig. 9.1). These are observed in either two or three wells, occur in shale horizons away from the high-energy sandy channels, and show a high diversity *in situ* fauna unaffected by transportation input (evidenced by calcareous and shallow-water foraminifera – see Chapter 10).

(1) *Haplophragmoides* cf. *bradyi* Horizon is observed in all three wells, although Plutao-1 shows only a limited number of specimens. It is characterised by the presence of *H.* aff. *bradyi* (sometimes in high numbers), close proximity to calcareous benthics including *Cibicidoides* spp. above, and followed down-hole by high proportions of *Glomospira* spp. Based on biostratigraphy of Plutao-1 this interval is around 17 – 18 Ma (Burdigalian).

(2) *Glomospira* Horizon is also observed in all three wells, and stratigraphically immediately precedes the *Haplophragmoides* cf. *bradyi* Horizon. This is characterised by high diversity purely agglutinated assemblages showing high numbers of *Glomospira* spp. (which are not observed lower in the wells but are observed higher up) and dominated by tubular fragments. Based on biostratigraphy of Plutao-1 this interval is around 19 – 20 Ma (Burdigalian).

(3) High diversity / low abundance Horizon is not observed in Plutao-1, and it has been inferred that this level coincides with the channel system there. In Saturno-1 and Venus-1 this level consists of shales with little or no sand content and no evidence of transportation. The purely agglutinated faunas are interpreted as *in situ* and show high diversity from Fisher's αx

although very low abundances. From the well tie (fig. 9.1) this interval may well span the Oligocene / Miocene boundary.

(4) *Textularia earlandi* Horizon appears in Plutao-1 and Venus-1 as an interval of medium to high abundance of *T. earlandi*, and is interpreted to be obscured by channel-sands in Saturno-1 (although some specimens are encountered here). This species occurs in extremely low abundances or is completely absent in overlying and underlying strata. Diversity remains unaffected or slightly higher over this interval. The overlying interval between this and the High diversity / low abundance Horizon is missing in all three wells due to channel sands. This horizon is intra-Upper Oligocene based on Plutao-1 biostratigraphy.

(5) *Portatrochammina profunda* Horizon immediately follows the *Textularia earlandi* Horizon down-hole, and is characterised by the first appearance of this species in high numbers as part of an entirely agglutinated fauna. The species *Discamminoides* sp. 1 is also present in low numbers. This horizon is only recorded in Plutao-1 and Venus-1, as Saturno-1 contains disruptive channel deposits over this interval. Diversity and abundance are both relatively high, with tubular fragments dominating. This horizon is intra-Upper Oligocene based on Plutao-1 biostratigraphy.

(6) High diversity *Reticulophragmium* Horizon is present in all three wells and is characterised by a high diversity agglutinated fauna, showing no species domination but the persistent occurrence of *Reticulophragmium* spp., and also *Paratrochamminoides* spp. and *Trochamminoides* spp. This level immediately follows the *Portatrochammina profunda* Horizon down-hole, and is also intra-Upper Oligocene based on Plutao-1 biostratigraphy.

(7) *Scherochorella congoensis* Horizon appears in Plutao-1 and Saturno-1 only, as Venus-1 contains disruptive channel sands at this level. This interval is dominated by the species *S. congoensis* (up to 50 % of the assemblage) and is a relatively thin lithologic package (as little as 40 m in Saturno-1). This species is not present in any other Horizon (at abundances greater than 1 or 2). A general decrease in diversity accompanies this interval and *Nothia robusta* also shows an increase. The species *Discamminoides* sp. 1 and *P. profunda* also occur persistently. This horizon is intra-Upper Oligocene based on Plutao-1 biostratigraphy.

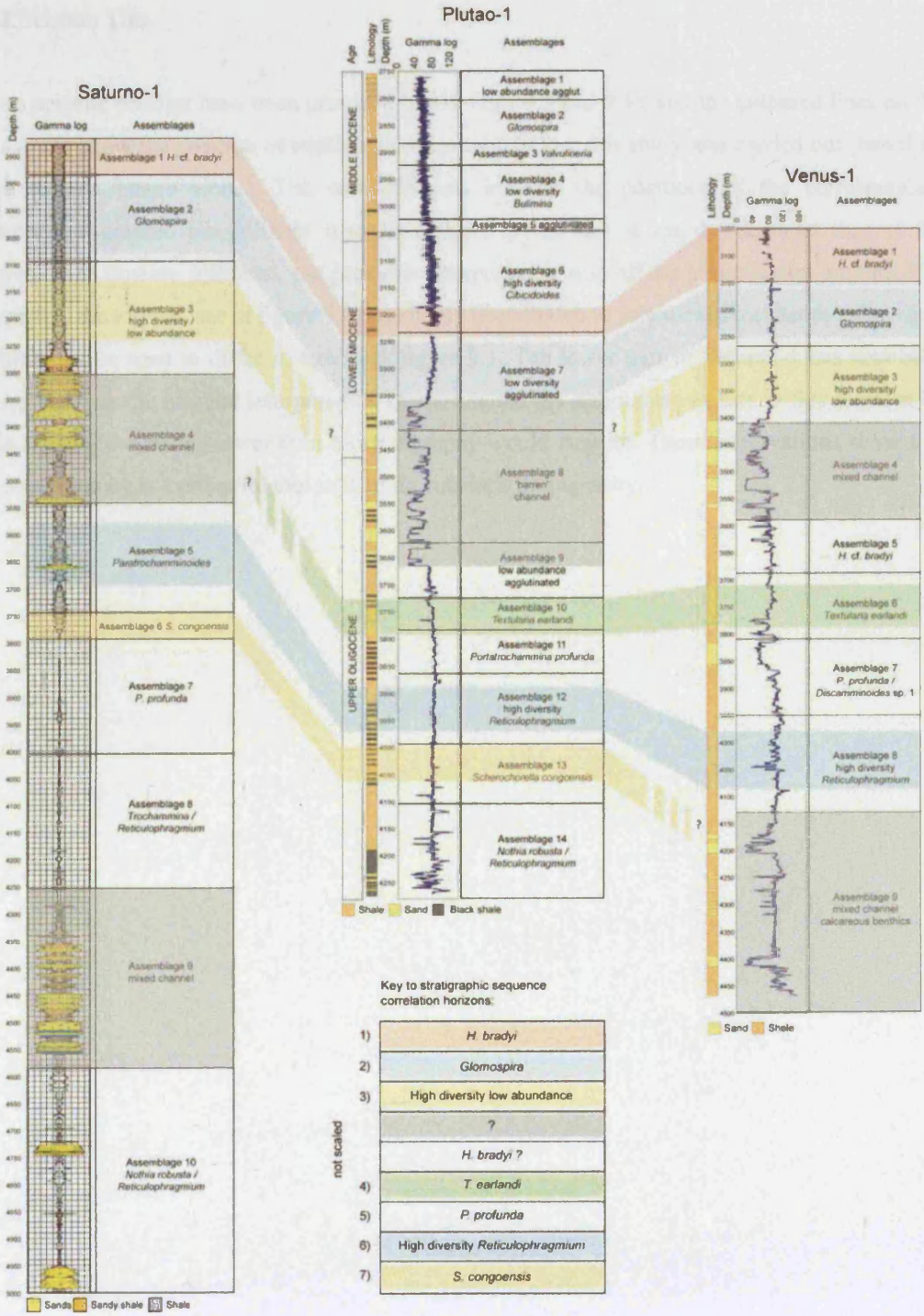


Figure 9.1 Correlation of chronostratigraphic horizons in Saturno-1, Plutao-1 and Venus-1. Vertical scale in measured depth (m). Shaded areas indicate channel disturbance that obscures signal.

9.2 Seismic Ties

Two seismic profiles have been provided by BP (figs 9.2 and 9.3), and the coloured lines on the diagrams show the position of stratigraphic ties used before this study was carried out (based on the seismic image alone). The coloured dots indicate the positions of the corresponding chronostratigraphic bio-horizons discussed above. From this it can be deduced that, if the assemblage ties are followed, the previous interpretation was off by a significant amount. For instance, the top red line in figure 9.2 has simply been drawn to join the darker (sandy) packages, which can be seen to differ in age from figure 9.1. The lower part of Saturno-1 has also been misplaced, as the original interpretation overestimated the sedimentation rate in this location by placing tie-lines much lower than biostratigraphy would suggest. These observations show that biostratigraphy is a powerful tool in helping constrain stratigraphy.

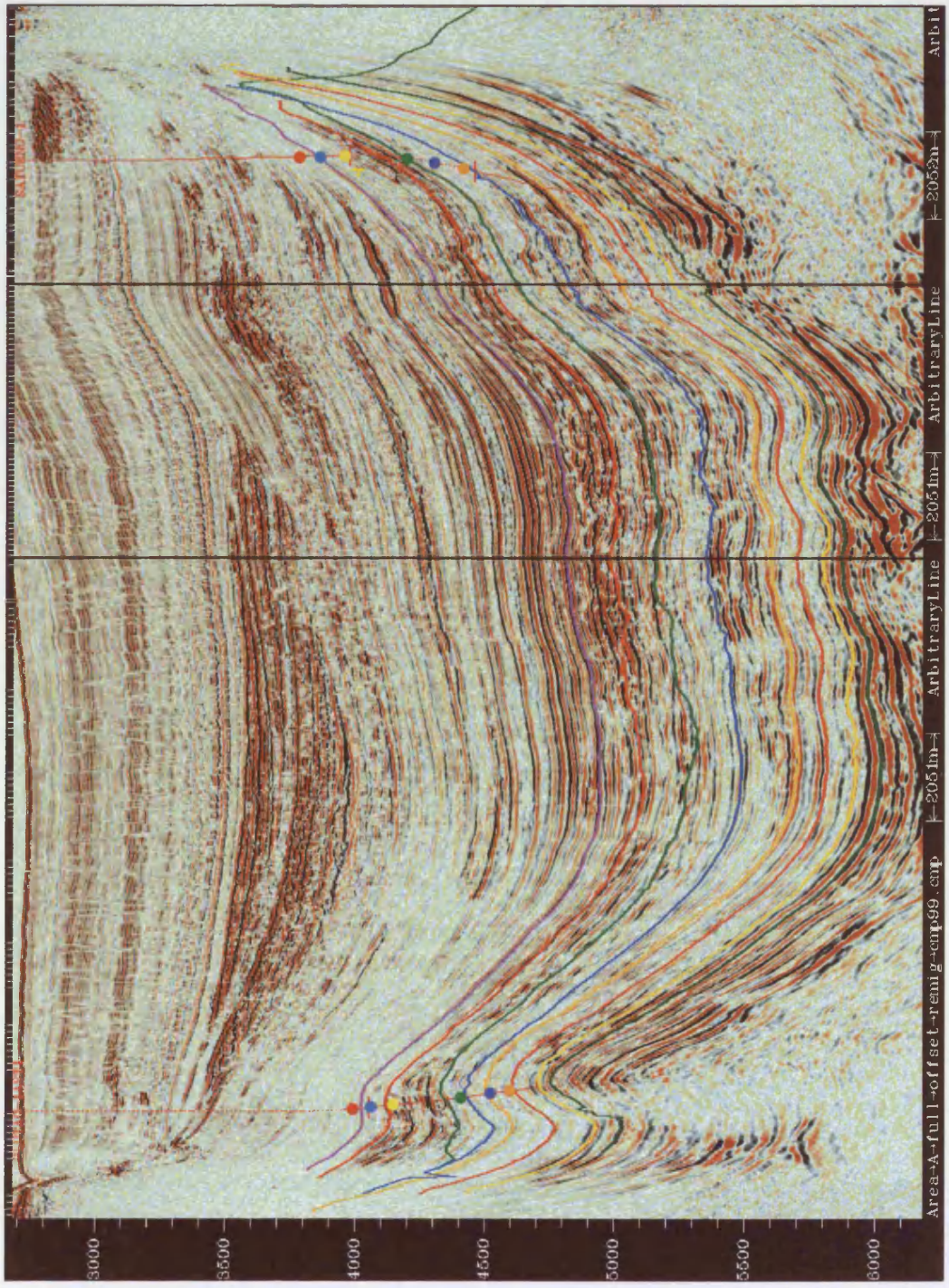


Figure 9.2 Seismic profile for Plutao-1 and Saturno-1 (with vertical exaggeration). Coloured lines indicate the stratigraphic ties used before this study. Coloured dots represent location of the chronostratigraphic Horizons defined in this chapter (colours same as fig. 9.1).

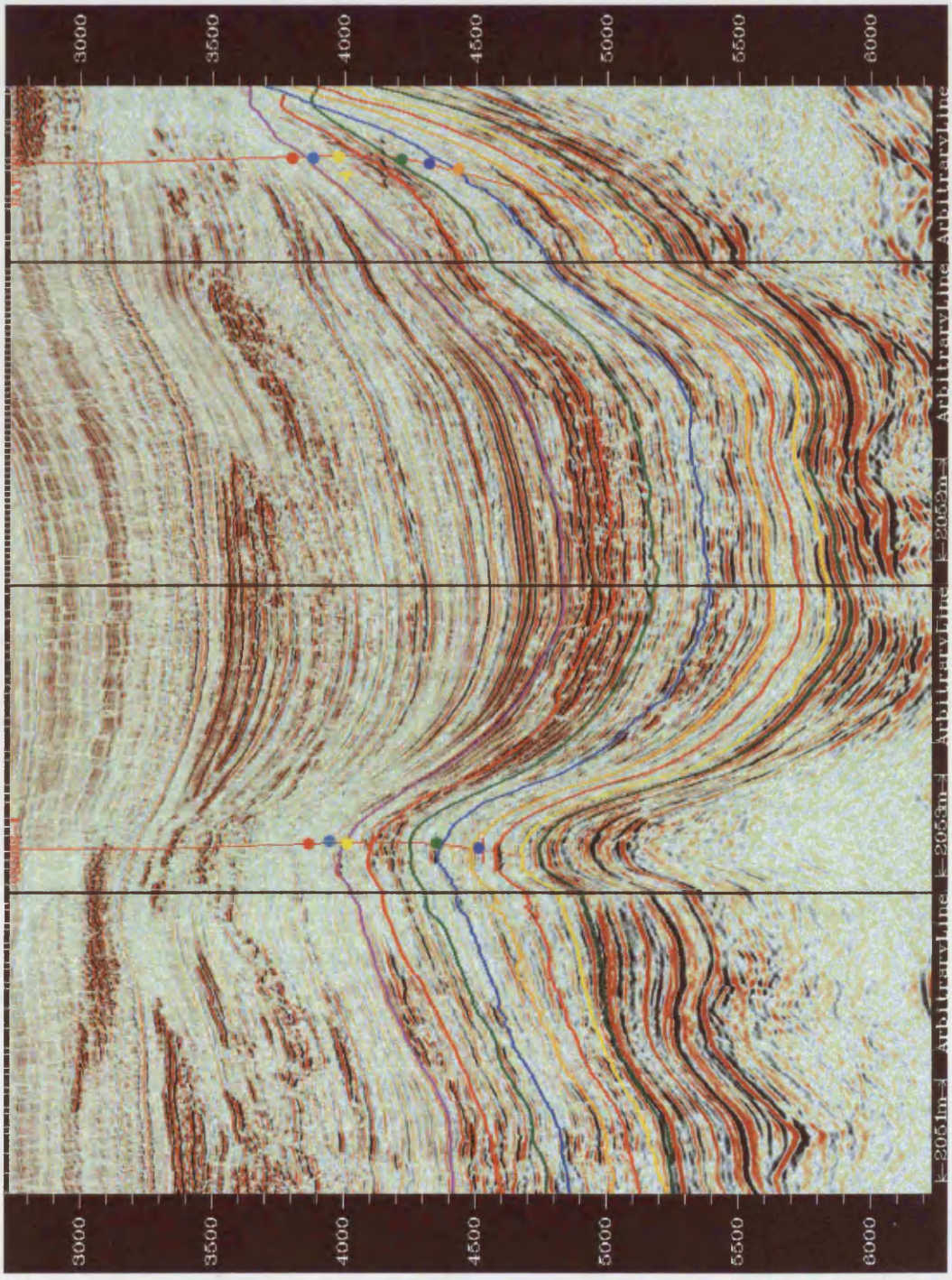


Figure 9.3 Seismic profile for Venus-1 and Saturno-1 (with vertical exaggeration). Coloured lines indicate the stratigraphic ties used before this study. Coloured dots represent location of the chronostratigraphic Horizons defined in this chapter (colours same as fig. 9.1).

CHAPTER 10 – DISCUSSION OF SEDIMENTOLOGY AND BENTHIC FAUNAS

10.1 Submarine Channel Morphology and Sedimentology

The modern Congo Fan contains a network of channels that extend from the mouth of the Congo River (as a canyon) to abyssal depths of over 5000 m, all of which are presently abandoned except for one which has been shown to be active (Savoye et al. 2000; Babonneau et al. 2002). Morphology of the active channel changes with depth and distance from the coast (fig. 10.1). At the continental shelf-slope break the canyon reaches maximum depth with incision of over 2000 m. The sinuosity of the channel is high and is classified as 'meandering' (Babonneau et al. 2002). Channel depth and sinuosity reduce with distance from the slope. The fan is composed of a stacked overlapping series of channel-levee components, as shown by seismic profile (Droz et al. 1996; Droz et al. 2003), along with lobes and overbanks (fig. 10.2).

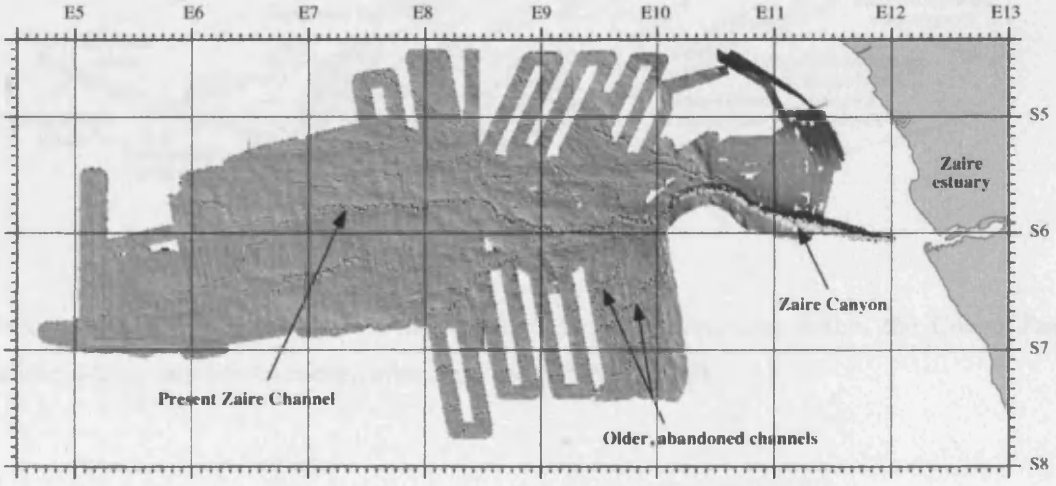


Figure 10.1 Bathymetric map of the Congo Fan showing the sinuous and far-reaching present-day channel and canyon (Babonneau et al. 2002).

Architectural classification of turbiditic submarine channels is hierarchical and therefore depends on the scale of the structures being examined. On the largest scale, submarine channels and canyons consist of three main architectural elements (fig. 10.3); these are channel, levee and overbank deposits. This simple classification is based on the structure of the active channel. Each component has its own sedimentological and micropalaeontological fingerprint which can be used to help identify the element in the geologic record after burial. Channel deposits contain

higher proportions of sand and gravel as energy levels are high. Sands are not generally present in the more distant overbank deposits. Figure 10.4 shows the channel and levee elements for a section of the active Congo channel. A topographic image and line drawing interpretation of a more distal section of the active Congo channel (fig. 10.6), presented by Babonneau et al. (2002), shows how the channel floor in this location (~ 4000 m bathymetry) is rather flat, and the sinuosity of the channel produces an abrupt flank on the outer-edge levee, and a shallower angle terraced structure on the inner-edge levee.

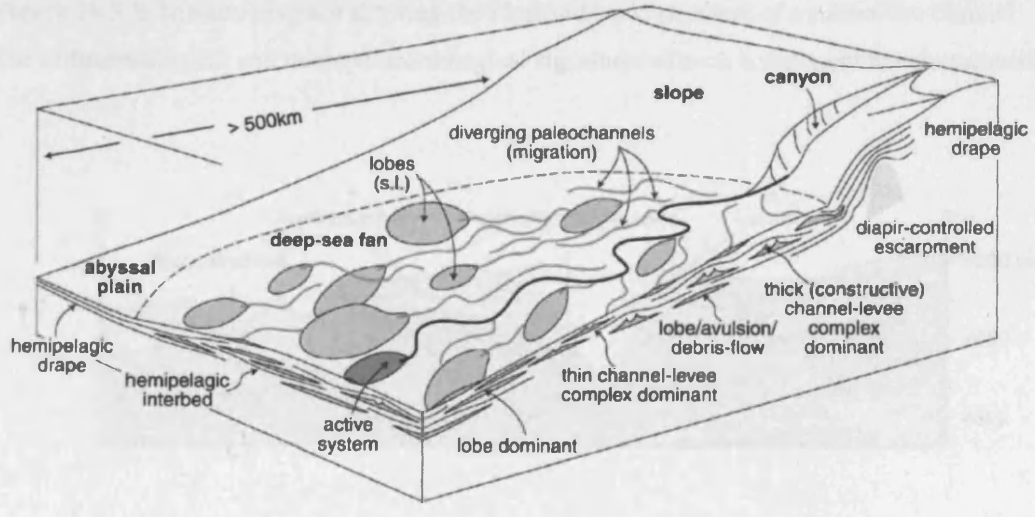


Figure 10.2 Idealised diagram of large-scale sedimentary structures within the Congo Fan (channel-levee and lobe elements) after Anka and Séranne (2004).

Channel morphology and structure has changed through time. Today sediment is transported down-channel as turbidity flows that occur during high rainfall and flooding, as documented by submarine cable breaks offshore Angola occurring at ~ 60 per 100 yrs (Heezen et al. 1964). Sedimentation is relatively low and the channel is therefore erosive, surrounded by hemipelagic and overbank deposits rather than stacked levees. Broucke et al. (2004) show this has been the case since the Burdigalian-Langhian (20-13 Ma), where channels are generally isolated within a hemipelagic background. Before this time however, in the Chattian (28-23 Ma), sedimentation was more rapid and channels are found within a complex of levee turbidites (fig. 10.5). The channel under study in this section (from Plutao-1) is Chattian-Aquitanian (~23 Ma) in age (see Chapters 5 and 6).

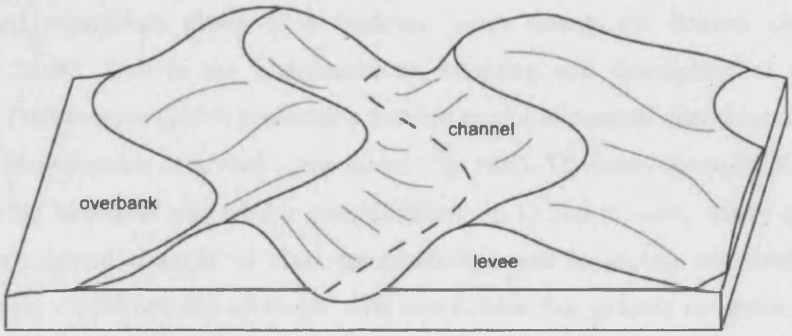


Figure 10.3 Schematic diagram showing the idealised basic structure of a submarine channel. The sedimentological and micropalaeontological signatures of each component are characteristic.

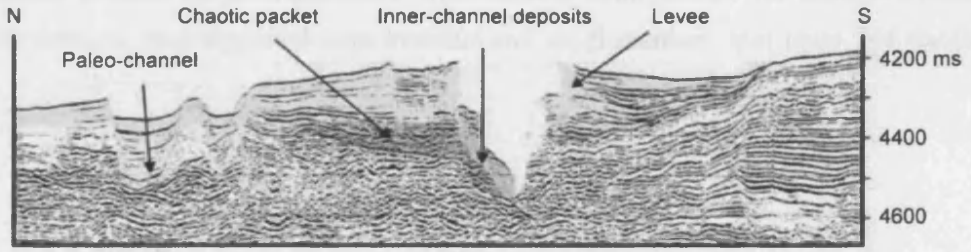


Figure 10.4 Seismic section (with architectural interpretation in colour) across the Congo Fan channel at ~ 3000 m water depth, also showing abandoned palaeochannels (Babonneau et al. 2002).

Jones et al. (2005) studied the micropalaeontology of an Eocene turbiditic channel in the Ainsa Basin of the south-central Pyrenees. They looked at samples from three locations along a channel outcrop; channel 'axis', channel 'off-axis', and 'levee/overbank'. Rogerson et al. (2006) studied benthic foraminifera from a Miocene shallow canyon system in Spain, and distinguished five assemblages from architectural elements within several channel axes, fans and open slope facies (fig. 10.7). Studies of Recent benthic foraminifera from canyon environments include Lundquist et al. (1997) from the U.S. Atlantic continental margin, Smith and Gallagher (2003) from the Bass Canyon of southeast Australia, and Koho et al. (2007) from the Nazaré Canyon of Portugal. A detailed study of the micropalaeontology of turbiditic channels was carried out by Dellamonica (2004), who studied outcrops of Eocene channels at several locations in the Hasret

Mountain and Baskil areas of eastern Turkey. The clastic deposits here were formed during the stretching and subsidence phase of a back-arc basin during the Eocene (Bingöl 1984; Dellamonica 2004). Due to the high-resolution sampling and description of the outcrops encountered, Dallamonica (2004) produced a detailed model of channel depositional architecture allowing the identification of several components (fig. 10.8). The main **channel-fill deposits** are characterised by lenticular and tabular conglomerates up to 500 m wide, where grading, sand injection, and vertical changes in clast composition linked to gravity are common. **Levee deposits** contain mudstones and siltstones, with interbedded fine-grained sandstones up to 50 m wide. **Overbank deposits** are characterised by mudstones, siltstones and sandstones in a sheet-like arrangement, with some lens-shaped sandstones and ripple features. **Upper channel fill** deposits consist predominantly of mudstone with thin sandstone beds, and are of variable thickness (up to 1000 m wide and 30 m thick). Usually above the channel fill, the **ribs deposits** consist of lenticular and tabular sandstones interbedded with siltstones and mudstones up to 100 m wide and 25 m thick, and sometimes show cross-bedding. **Mud slumps and debrites** contain chaotically-arranged mud-supported large boulders and conglomerates, mud chips and shelfal faunas.

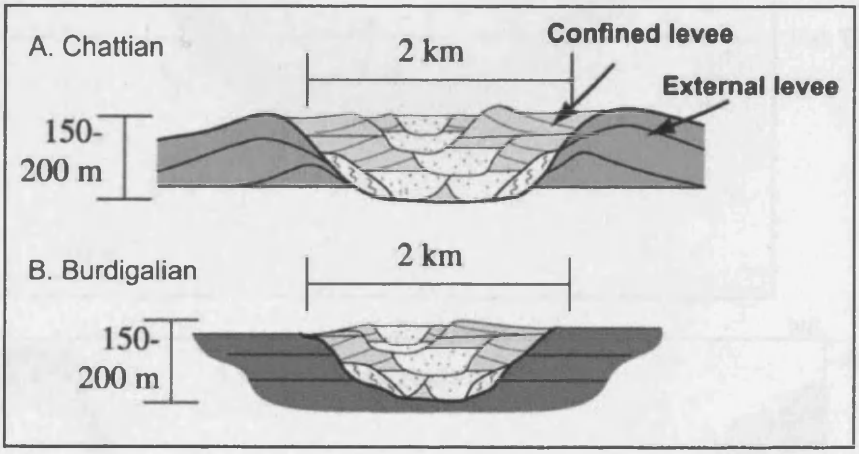


Figure 10.5 Schematic sections of Congo Fan channel complexes in **A** Chattian and **B** Burdigalian deposits. Younger channels are generally confined within hemipelagic muds (Broucke et al. 2004).

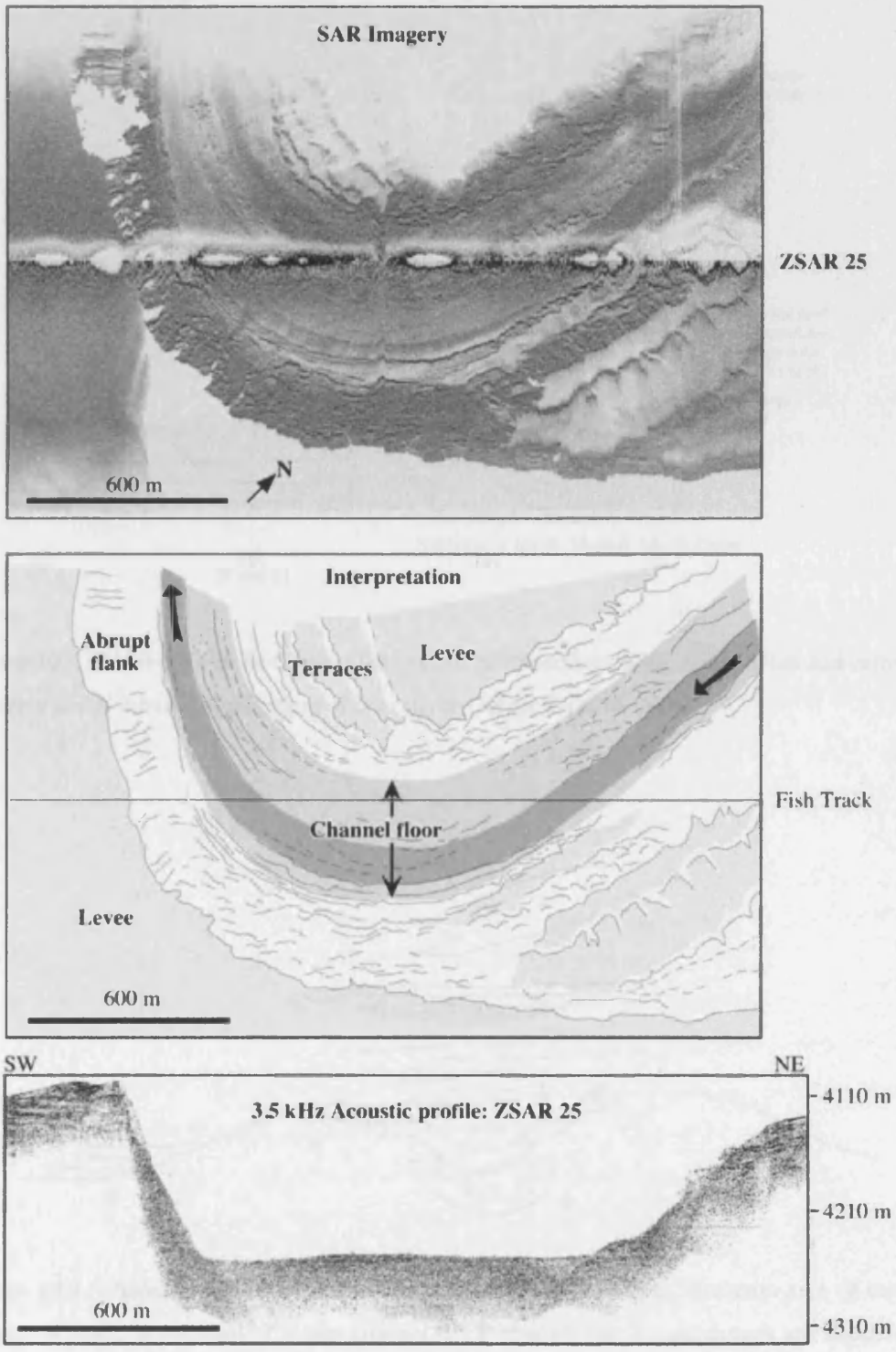


Figure 10.6 Image of a section of active channel in the Congo Fan (water depth ~ 4000 m), with line-drawing interpretation and bathymetry profile (Babonneau et al. 2002).

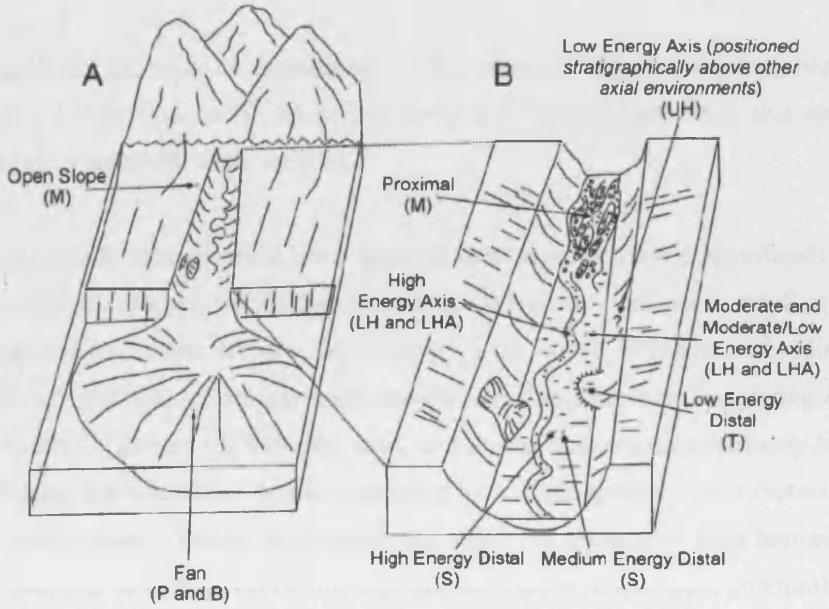


Figure 10.7 Model of El Buho Canyon fan system (SE Spain) showing **A** slope, fan and canyon elements and **B** internal architecture of the canyon (Rogerson et al. 2006).

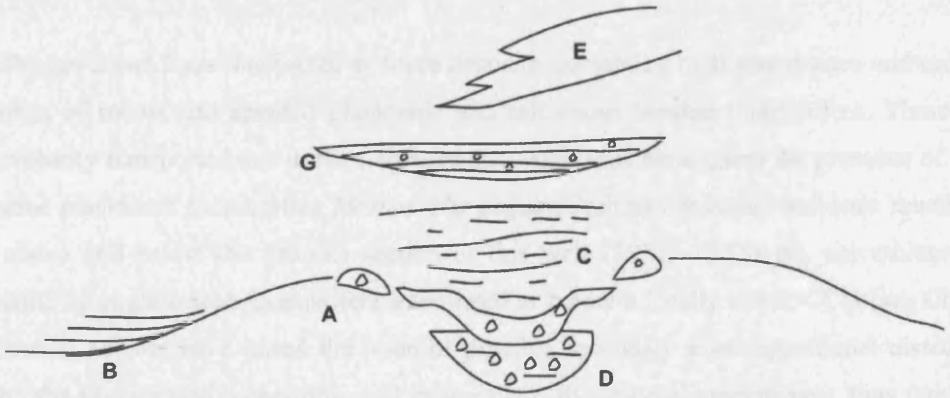


Figure 10.8 Schematic section of submarine channel from the Hasret Mountain area of eastern Turkey; **A** levee, **B** overbank, **C** upper channel fill, **D** channel fill, **E** mud slumps and debrites, **G** ribs. (After Dellamonica 2004)

10.2 Channel and Levee Associations

The only significant recovery of foraminifera within channel horizons was from the sidewall cores in Plutao-1 (see Chapter 6). Therefore analysis of assemblages from this sedimentary environment refers mainly to these samples.

Micropalaeontological data retrieved from sidewall core samples allows identification of both levee and channel associations within the section (fig. 10.10). Assemblages 1 and 4 (see also fig. 6.7) are interpreted as channel deposits, and contain a wide variety of faunas and sedimentology (see also figs 6.5 and 6.6). Cores generally have a very low recovery, suggestive of poorly-lithified sand, and the gamma log indicates sands and shales. Samples are commonly barren, and sometimes contain low abundance faunas dominated by a single species. These factors suggest a high energy environment whereby foraminifera are either not present, or have become strongly sorted and winnowed by differential current strength and motion. Either way, foraminifera do not live in this environment. This assemblage resembles that of the 'conglomeritic channel-fill element' of Dellamonica (2004), who recovered a very low abundance and diversity fauna in this element. It also has similar features to the channel 'axis' assemblage of Jones et al. (2005), which was reported to contain low abundance and diversity with high variability. Both Rogerson et al. (2006) and Koho et al. (2007) also report barren or very low diversity assemblages within the high energy channel axis and relate it to high energy conditions.

Assemblages 2 and 3 are interpreted as levee deposits, containing high abundances and medium diversities of robust and abraded planktonic and calcareous benthic foraminifera. These tests were probably transported due to their abraded and calcareous nature, and the presence of some Paleogene planktonic foraminifera *Morozovella aequa* (Cushman & Renz) indicates reworking. Both above and below the channel section of this well (3670 – 3370 m), assemblages are dominated by agglutinated foraminifera interpreted as below a locally raised CCD (see Chapter 11). Several authors have raised the issue of possible secondary post-depositional dissolution forming the agglutinated faunas observed in so-called 'flysch-type' assemblages, thus removing a hypothetical calcareous component (e.g. Murray and Alve 1994). Several factors discount this hypothesis. 1) If secondary dissolution did remove an original calcareous component in the overbank assemblages above and below this channel (fig. 10.11), we would expect this phenomenon in the channel itself. Pore waters would have been even more corrosive here as pore space is much larger within sandstone. 2) 'Flysch-type' assemblages are more common during times of global CCD rise, for example during the Paleocene-Eocene boundary and latest Early

Eocene (Kaminski & Gradstein 2005), leaving the question of why secondary dissolution would have produced this signal. 3) The $\delta^{13}C$ record in the Miocene section of Plutao-1 (fig. 5.17) mirrors increase in calcareous test percentage, implying benthic foraminifera are responding to contemporary ocean chemistry fluctuations and not post-depositional dissolution.

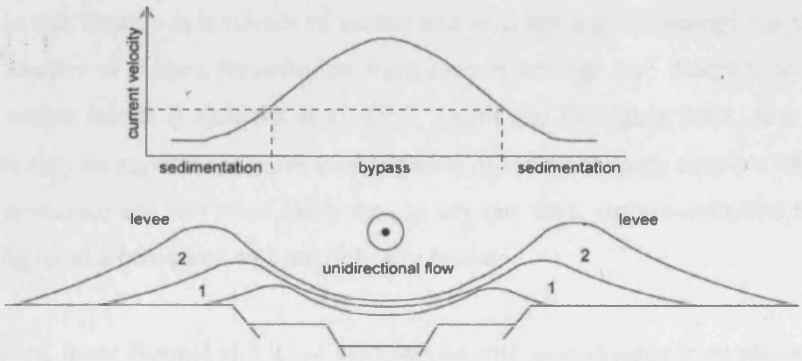


Figure 10.9 Idealised schematic diagram of submarine current energy and associated levee building. Levee associations 1 and 2 are marked. After Dellamonica (2004).

The most likely explanation for calcareous foraminifera appearing in the channel is therefore re-depositing from higher up the slope. The gamma log shows that the majority of this horizon consists of shale with rare sandy levels. These features most resemble the levee assemblages described by Dellamonica (2004), who reported 55-75% planktonic foraminifera, only rare agglutinated foraminifera, and calcareous benthic foraminifera dominated by epifaunal morphogroup D. Furthermore Dellamonica (2004) proposed four levee associations relating to distance from the channel axis (fig. 10.9), recording a general increase in planktonics and decrease in morphogroup D with distance from channel. These trends are apparent when moving from Assemblage 2 to 3, which therefore allows recognition of two levee associations (fig. 10.10). The movement of the levee over time away from the channel represents a decrease in energy, and this is picked up on the gamma log as a level with low sand content. It is unclear why a decrease in D should result from this, but hydrodynamic sorting may be a cause.

In both Saturno-1 and Venus-1 several horizons of generally poorly preserved calcareous foraminifera are recorded in otherwise purely agglutinated wells (figs 7.1 and 8.1), and have

been interpreted as reworking by turbidity flows. This is supported by the sandy signal from the gamma logs in the majority of these instances.

Significant transportation of foraminifera within canyon settings has not been detected in a number of other studies. Although Rogerson et al. (2006) didn't find significant reworked material (but only an *in situ* fauna throughout the entire canyon-fan system), the greatest palaeodepth in this locality is hundreds of meters and so is not a good analogy for the deep-sea Congo Fan. Studies of Recent foraminifera from canyon settings also detect little transported components within faunas (Lundquist et al. 1997, Smith and Gallagher 2003, and Koho et al. 2007), but this may be expected as mass transportation of sediment along canyons takes place on a geological timescale and it is most likely that, at any one time, surface-collected foraminifera from grab samples and box-cores will return *in situ* faunas.

When comparing these channel and levee associations with assemblages from above and below the sandy channel horizons in Plutao-1, a clear difference in composition can be seen (fig. 10.11). We would expect the sedimentological associations surrounding the channel complex to be overbank deposits (see section 10.1 above) from the Broucke et al. (2004) analysis of Congo Fan sediments (fig. 10.5), and the very high sedimentation rates also suggest this. The overbank faunas from the Miocene and Oligocene sections of Plutao-1 are dominated by agglutinated foraminifera composed largely of tubular morphogroups as well as most others. Diversity is much higher than in the channel complex. These factors point to a fauna that is *in situ* and was thriving in this environment, at some distance from the channel, with high sedimentation rates. This association is analogous to the overbank assemblages described by Dellamonica (2004), which are recorded as containing equal numbers of agglutinated and calcareous foraminifera of high diversity and dominated by tubular morphogroups. Agglutinated foraminifera are probably not present within the channel and levees as the high energy environments here would have destroyed these more delicate tests.

The most significant finding of this micropalaeontological analysis is the dramatic change of fauna at the boundary of Assemblages 1 and 2 (suggesting a shift from channel to levee sedimentation) which is not apparent from the gamma log alone, and shows the potential for micropalaeontology as a tool to subdivide intra-reservoir units of differing physical properties.

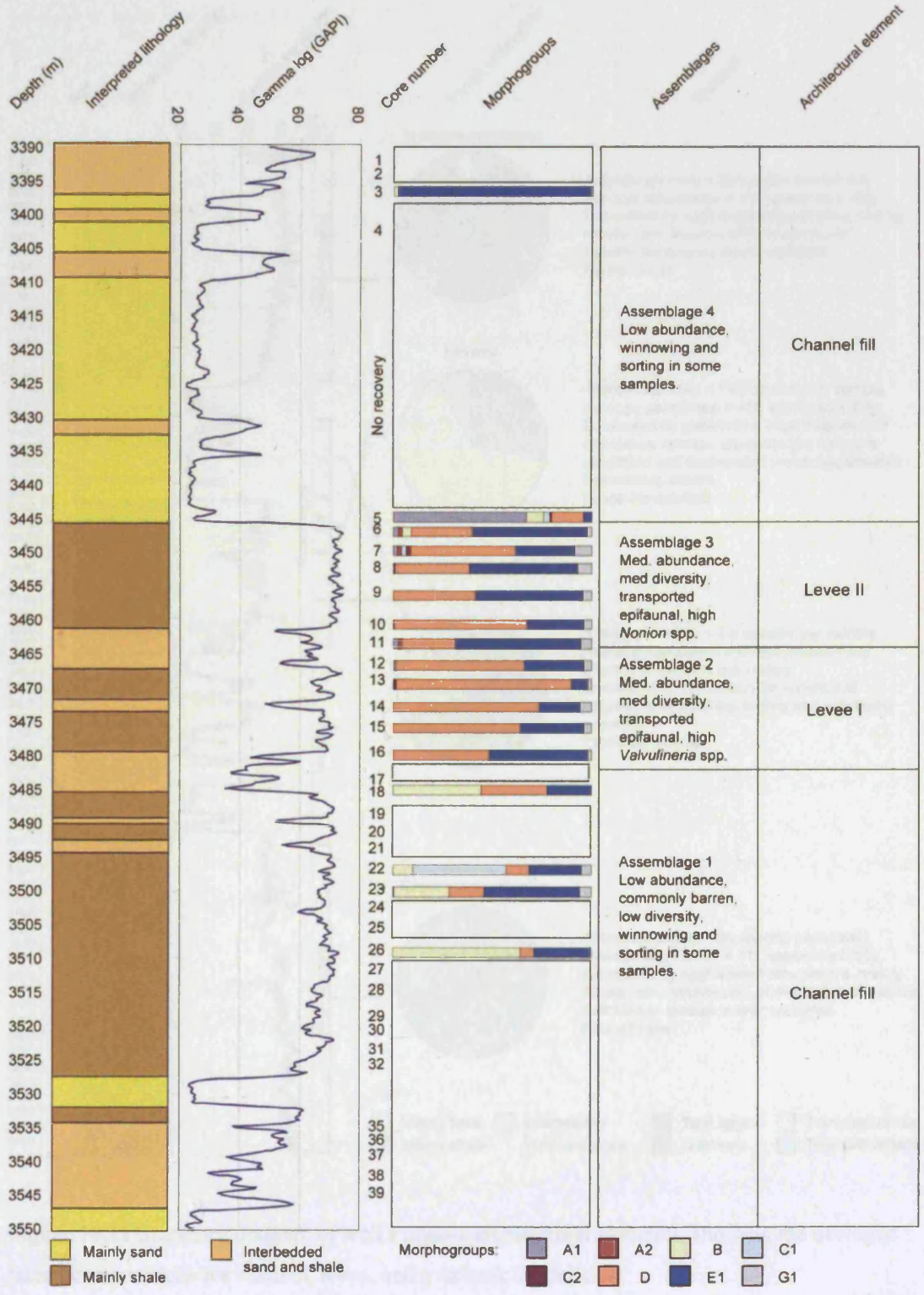


Figure 10.10 Summary diagram of sidewall core assemblages and architectural elements, against lithology and morphogroup analysis.

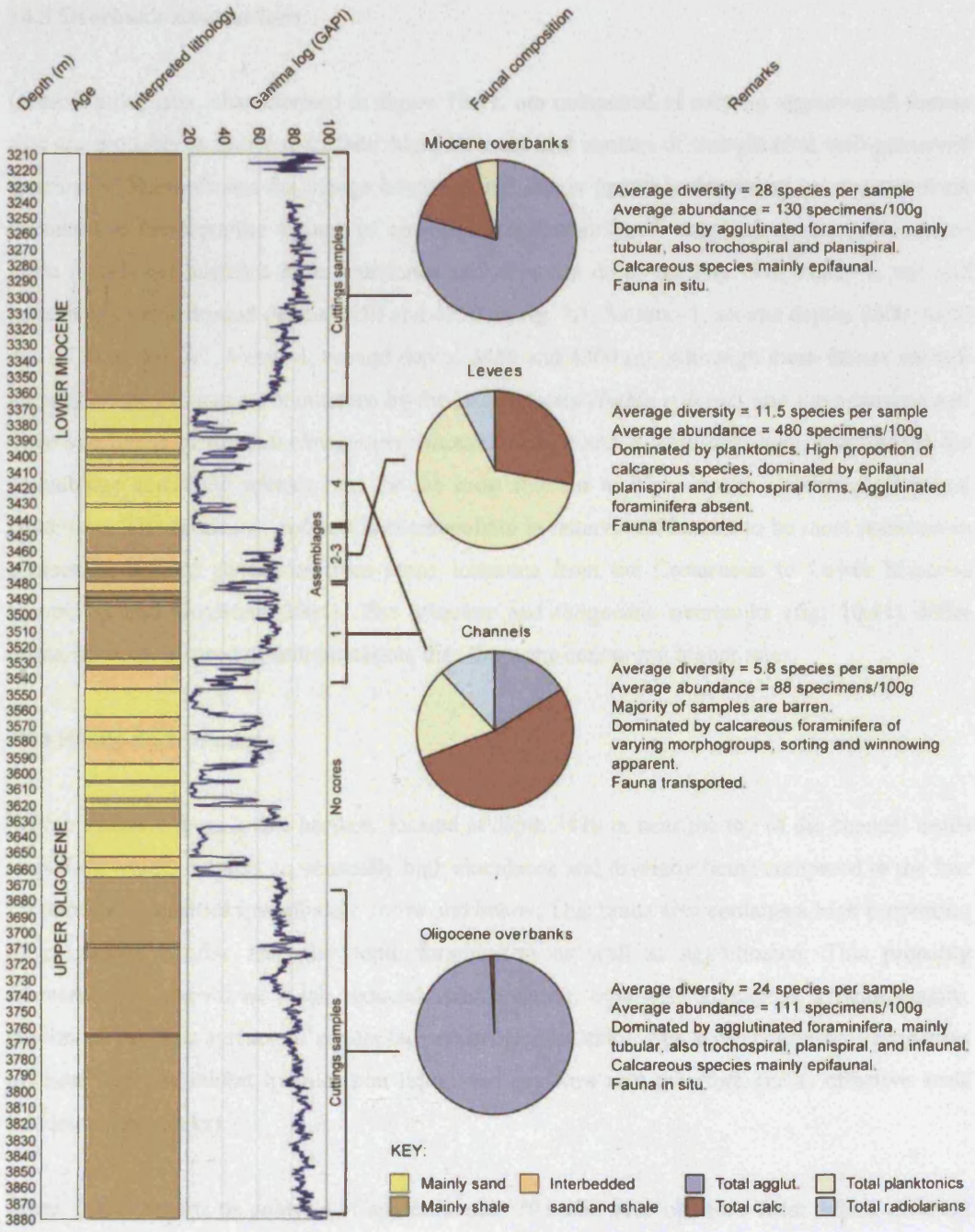


Figure 10.11 Summary diagram of well Plutao-1 architectural elements, showing the averaged faunal compositions for channel, levee, and overbank deposits.

10.3 Overbank Associations

Overbank deposits, characterised in figure 10.11, are composed of varying agglutinated faunas that are probably *in situ* due to their high diversity and content of non-abraded well-preserved specimens. These faunas do change however, and this is probably dependent on distance from channel and therefore the amount of energy and sediment that is supplied. In several locations close to channel horizons both abundance and diversity drops off (fig. 5.8, Plutao-1, top and bottom of section around depths 3650 and 4230 m; fig. 7.1, Saturno-1, around depths 3600, 4300 and 4750 m; fig. 8.1, Venus-1, around depths 3450 and 4300 m). Although these faunas are still all agglutinated in nature, dominance by the large species *Nothia robusta*, and the persistence of large specimens of *Reticulophragmium rotundidorsatum* and *R. acutidorsatum*, characterise the assemblage and these species may be the most tolerant to high energy / sedimentation rate conditions. The species *N. robusta* is cosmopolitan in nature, and known to be most common in coarsening upward sequences from many locations from the Cretaceous to Lower Miocene (Kaminski and Gradstein 2004). The Miocene and Oligocene overbanks (fig. 10.11) differ primarily in their speed of sedimentation, the Oligocene containing higher rates.

10.4 Hemipelagic Shales

Within Plutao-1 there is one horizon, located at depth 3410 m near the top of the channel sands (figs 5.4), which contains an unusually high abundance and diversity fauna compared to the low foraminiferal densities immediately above and below. This fauna also contains a high proportion of calcareous benthic and planktonic foraminifera as well as agglutinated. This probably represents an interval of much reduced sedimentation, otherwise known as a hemipelagite, maximum flooding surface or condensed section (Jones 2006). The sedimentological properties of these deposits inhibit hydrocarbon liquid and gas flow and therefore act as effective seals (mudstone cap-rocks).

Jones (2006) reports on analysis of approximately 30 wells from offshore West Africa covering the Oligocene-Miocene, and finds by far the most prominent and continuous mudstone cap-rock appearing within the Aquitanian. This is within the age estimated for this section (see Chapter 5) and may well be correlatable.

10.5 Conclusions

1. Analysis of sidewall cores from the channel complex of well Plutao-1 reveals a varying fauna, sometimes with high abundance, dominated by reworked poorly preserved planktonic foraminifera and epifaunal calcareous benthic foraminifera, and at other times barren or with very low abundance. Poor preservation, the presence of mainly robust forms, and the occurrence of winnowing and sorting, all suggest a re-deposited fauna transported from higher up the slope. At least some of the planktonic foraminifera are reworked from the Eocene.

2. Characteristic assemblages marking the channel and levee elements of the complex are recognised. Samples either barren or dominated by single species are interpreted as channel components, due to high energy and the winnowing effect of currents. Samples with very high abundance, dominated by re-deposited planktonics and epifaunal benthics, are interpreted as levee components with reduced energy and generally lower sand content. Two levee components are differentiated by comparison with outcrop studies from other authors.

3. The shift from channel to levee deposition can be detected only on the basis of micropalaeontological content, and is not marked by any change in the gamma log. All other boundaries are coincident with sedimentological changes in the sand/silt ratio.

4. Overbank faunas differ from both levee and channel faunas in containing a diverse agglutinated assemblage with very little calcareous content, mainly composed of tubular fragments and very low in infaunal varieties. This fauna is interpreted as *in situ* and can be seen to increase in diversity and abundance with distance from channels in all three wells. The species *Nothia robusta* occurs in high numbers, and *Reticulophragmium* spp. remains persistent, within low diversity assemblages that are close to channels and probably represent the most tolerant species to high energy conditions.

CHAPTER 11 – DISCUSSION OF MIOCENE PALAEOENVIRONMENT AND PALAEOCEANOGRAPHY

Recovery of Miocene sediments in this study is restricted to the upper section of well Plutao-1 (fig. 9.1, 2750 – 3400 m), and the following discussion is therefore based on this section. As well as faunal and sedimentological data, $\delta^{18}O$ and $\delta^{13}C$ data has been collected from this interval. These data, along with a relatively well-constrained age model for this section (fig. 5.1), allow a detailed palaeoenvironmental and palaeoceanographic analysis for the Early-Middle Miocene at this site. Faunas show close affinities to those of the Gulf of Mexico, eastern Venezuelan Basin and Central Paratethys.

11.1 Caving and Reworking

The samples in this study have been collected as rock cuttings (ditch cuttings) and are therefore susceptible to down-hole contamination (caving). Although some specimens have been found to be caved (e.g. 1 specimen of *G. praemenardii* in sample 2930 m – see 5.1 Biostratigraphy and Age / Depth Model; several possible specimens of upper bathyal *Cibicidoides pachyderma* – see section 11.2 below), there is no observed large-scale caving and therefore overall trends in species abundances are regarded to be real.

Reworking in these samples is a relatively unknown quantity. Evidence of shallow water species transported down-slope (e.g. *Ammonia* spp. in samples 3130 to 3190 m) is sparse, and therefore reworking is also regarded as an insignificant component (see section 11.2 below).

11.2 Palaeobathymetry

Analysis of bathymetric ranges of commonly occurring species in this study (fig. 11.1) reveals a palaeobathymetric depth of middle – lower bathyal (~1000 m) during the Lower – Middle Miocene. Two common species with lower depth ranges of middle bathyal in the Gulf of Mexico are *C. crebbsi* (Picou et al. 1999, although Van Morkhoven et al. 1986 record upper bathyal) and *S. bulloides* (Van Morkhoven et al. 1986). Species *L. calcar* and *C. pachyderma* are both upper bathyal forms (Van Morkhoven et al. 1986), but occur in low numbers and may have been transported down-slope or occur at differing ranges in this location. The species *A. clavata* has been reported as a middle bathyal form in the Gulf of Mexico, but ranging shallower elsewhere (Kaminski and Gradstein 2005). Both *G. soldanii* (Jones 1994 – North Atlantic) and *P. renzi*

(Van Morkhoven et al. 1986 – Gulf of Mexico) are middle bathyal to abyssal species. The species *C. havanensis* persistently occurs through the section, and has an upper depth limit of lower bathyal in the Gulf of Mexico (Van Morkhoven et al. 1986). The species *R. orbicularis* is a modern form recorded at abyssal depths in the South Pacific (Jones 1994). However the extinct species *R. rotundidorsatum*, believed to be an evolutionary ancestor of *R. orbicularis*, is strictly bathyal (Kaminski and Gradstein 2005). It is therefore postulated that the early form of *R. orbicularis* had a shallower depth range in the Early – Middle Miocene.

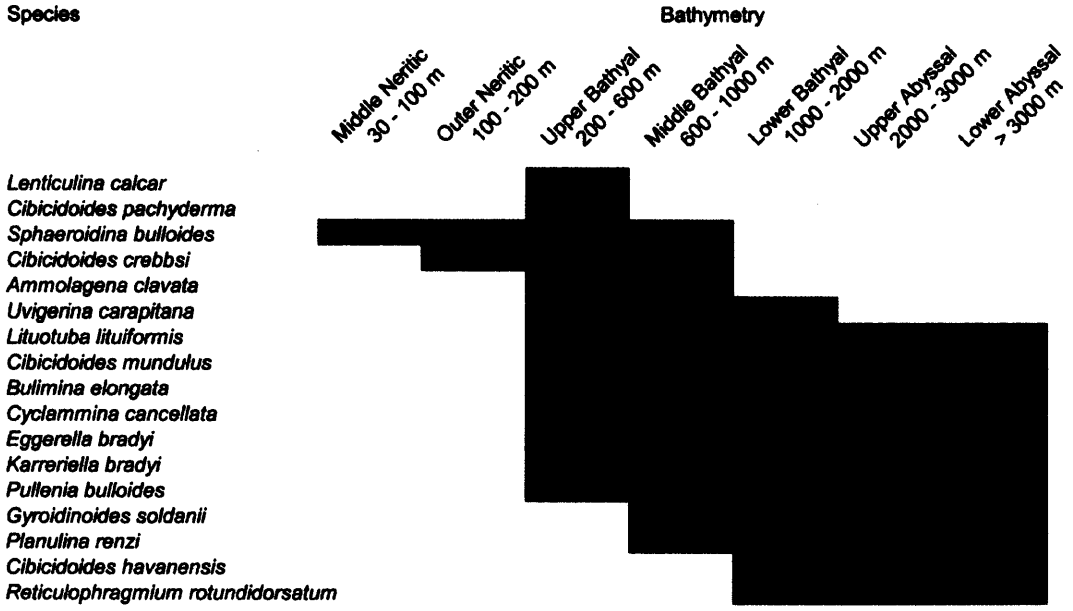


Figure 11.1 Palaeobathymetric ranges of important species from the Miocene section of Plutao-1. Species such as *C. crebbsi* and *C. havanensis* are persistent throughout most of the section, suggesting palaeobathymetry did not change significantly over this interval. Ranges compiled from Van Morkhoven et al. (1986), Picou et al. (1999), Kaminski and Gradstein (2005) and Jones (1994).

Morphogroup analysis of agglutinated foraminifera (fig. 5.13) shows the tubular group M1 making up about 50% of assemblages. According to Jones and Charnock (1985), basing their morphogroup analysis on numerous sites from the northeast Atlantic, the tubular suspension-feeding group only start to dominate by 'middle bathyal, 1000 – 1650 m' where they make up 50 % of the agglutinated fauna. In addition, their morphogroups B (surface-dwellers) and C

(infauna) make up the majority of the remaining assemblage, which is in agreement with our equivalent groups M2a, M2b, M3a and M4b. It remains a strong possibility however that these morphogroups (especially M1) are not depth-dependent.

11.3 Palaeoecology

Palaeoenvironments appear to have been largely conducive for foraminiferal growth as evidenced by the wide diversity and abundances observed in most samples, which has also been recorded in comparable turbiditic fan environments (e.g. Brouwer 1965 – Europe; Jones 1999 – North Sea; Fontanier et al. 2005 – Bay of Biscay). In deep-sea environments, factors affecting foraminiferal populations include organic matter input and dissolved oxygen in pore waters (Jorissen et al. 1995; Altenbach et al. 1999; Preece et al. 1999; Van der Zwaan et al. 1999; Gooday et al. 2000), level of the Calcite Compensation Depth (CCD) and energy levels in the benthic boundary layer (Kaminski 1985; Schmiedl et al. 1997). Altenbach et al. (1999) and Licari and Mackensen (2005) recorded productivity variations, and their associated changes to levels of organic matter and oxygen at the sea-floor, as the only significant environmental variable at all latitudes in the Atlantic and offshore West Africa today. Larger studies of Recent benthic foraminifera from the southeastern Atlantic (Schmiedl et al. 1997) found organic carbon / oxygen levels, carbonate corrosiveness, and energy levels to be the principle factors affecting deep-sea communities. Preece et al. (1999) found variations in TOC (Total Organic Carbon) through a Miocene section of the Congo Fan to be the major factor explaining faunal fluctuations through time, this phenomenon being ultimately related to oxygen levels.

It can be observed that a reduction in abundance and diversity at levels of increased sand content occurs in both the Low Diversity Agglutinated Assemblage 1 and the Low diversity agglutinated Assemblage 7 (figs 5.4 and 5.5), and propose that the associated increased energy levels caused environmental deterioration (see Chapter 10). A significant reduction in sand content from depths 3230 m upwards corresponds with a significant increase in diversity and appears to be a sedimentological change perhaps relating to a shift from higher energy (largely silt-loaded) turbidites to lower energy turbidites. The following High Diversity *Cibicidoides* Assemblage 6 probably represents a period of relatively stable, well-oxygenated, low-energy conditions associated with a good supply of organic matter. Morphogroup results from this section (fig. 5.13) show a dominance of the calcareous epifaunal morphogroup which lends evidence for well-oxygenated bottom waters. Abundance generally increases towards the top of this interval (3120 – 3050 m), which may be the result of condensed sections as Haq et al. (1987) records

major sea-level fluctuations at the beginning of the Early Miocene around 15 and 16 Ma (fig. 5.18). Increased abundance levels can also be the result of decreased predation caused by reduced oxygen levels. This is regarded as unlikely due to the epifaunal nature of the assemblages (see section 11.6 below). Agglutinated Assemblage 5 shows a reduction in diversity due to the removal of the calcareous foraminifera (agglutinated diversity remains high), and may be caused by a locally reduced CCD rather than reduced oxygen.

The following *Bulimina* Assemblage 4 coincides with much-reduced diversity and is the result of a more stressed ecological environment. Morphogroup analysis (fig. 5.13) shows the calcareous Shallow Infauna dominating suggesting lower oxygen. This may be the result of productivity changes and / or bottom-water circulatory slow-down. We regard the former to be more likely as this interval also coincides with global cooling (fig. 5.16), a phenomenon known to increase upwelling in the southeastern Atlantic during glacial periods due to an increase in Trade Wind strength (e.g. Stuut et al. 2002 – see section 11.6 below). The following *Valvulineria pseudotumeyensis* Assemblage 3 shows continuing low diversity and a resurgence of the Epifaunal morphogroup largely due to the dominance of the species *V. pseudotumeyensis*. Kaiho (1994) listed *Valvulineria* spp. as a suboxic indicator. In addition, low diversity and faunal dominance is characteristic of stressed environments and suggests a continuation of low oxygen conditions.

The *Glomospira* Assemblage 2 shows continuing low diversity, partly caused by the removal of the calcareous assemblage. Agglutinated morphogroups show a reduced domination of tubular suspension-feeders (M1), and also an increase in the flattened surficial epifaunal group (M3a) mainly the result of increased *G. charoides*, *G. gordialis* and *G. irregularis*. The species *G. charoides* has been found to respond positively to high organic matter flux from levels termed the '*Glomospira* facies' (also including the species *G. gordialis* and *G. irregularis*) in the North Atlantic, Mediterranean and Alpine-Carpathian Flysch in the Early Eocene (see Kaminski and Gradstein 2005). Conversely, this species has been recorded at oligotrophic levels of reduced organic matter flux in the Mediterranean (De Rijk et al. 2000). Kaminski (1988) also found *G. charoides* in high abundance close to natural hydrocarbon seeps in the Gulf of Mexico, and Jonasson et al. (1995) recorded high levels of *G. gordialis* near a hydrothermal venting site in the northeast Pacific. In the current setting, coupled with low diversity, an increase in these species is probably indicating continuing low oxygen and high organic carbon flux conditions.

11.4 Early-Middle Miocene Palaeoceanography

The Early-Middle Miocene represents an important time in Earth's history as it was a transitional phase between the Paleogene climatic high and the 'icehouse' climate of the Neogene. The Early Miocene witnessed a series of fluctuating Antarctic glacial and interglacial episodes which culminated in the warmest period of the Neogene around the early/middle Miocene boundary, before a significant cooling phase and the final transition into the cold icehouse world at around 14 Ma (Miller et al. 1987, 1991; Flower and Kennett 1994, 1995; Flower et al. 1997; Holbourn et al. 2005).

Early Miocene oceanic circulation is relatively poorly understood due in part to widespread unconformities in ocean sediments at this interval (Keller and Barron, 1983; Wright et al. 1992). Barron and Keller (1982) record a widespread deep-sea hiatus at around 15 – 16 Ma which they related to increased bottom current strength associated with polar cooling. Carbon isotope signals are however thought to indicate that there was only a small contribution of Northern Component Water (NCW) to the South Atlantic at this time (Wright et al. 1992). The formation of warm saline deep water in the Indian Ocean has been suggested by several authors (Woodruff and Savin, 1989; Flower and Kennett 1994, 1995), and may have contributed a significant component of Atlantic waters through the open Tethys Ocean at this time. Around the early/middle Miocene boundary a major reorganisation of global circulation occurred that resulted in the well-documented 'silica switch', representing a change in the locus of biosilica production from the North Atlantic to the Indo-Pacific Oceans (Barron and Baldauf 1990). This coincided with the intermittent closure of Tethys (Jones 2006) and the emergence of the Iceland Plateau (Schnitker 1980; Flower et al. 1997). The final transition to icehouse world at around 14 Ma has been found to be coincident with a period of prolonged Antarctic low summer insolation creating the boundary conditions needed for large-scale cooling (Holbourn et al. 2005).

11.5 Calcite Preservation and the Link with $\delta^{13}C$

The correlation between calcite preservation (percent calcareous foraminifera) and $\delta^{13}C$ observed in the samples from this section (fig. 5.17) is striking, as increasing levels of $\delta^{13}C$ are mirrored by increase in calcareous content and vice versa. The link between better calcite preservation in oceanic sediments and rising levels of $\delta^{13}C$ has been well documented at this time (Woodruff and Savin, 1991), a period of sustained high levels of $\delta^{13}C$ from about 17.5 Ma corresponding to the well known Monterey Carbon Isotope Excursion (Vincent and Berger 1985; Zachos et al. 2001).

Greater carbon burial for whatever reason can be expected to reduce levels of $\delta^{13}C$ in the water column, and as a consequence reduce levels of CO_2 in the atmosphere. This is explained in the simplified carbon cycle shown in figure 11.2. The lighter carbon isotope ^{12}C is preferentially taken up by living organisms, the greater burial of which increases levels of the heavier isotope ^{13}C in the water column and is reflected in benthic foraminiferal tests as increased $\delta^{13}C$. The greater burial of carbon also acts to reduce the levels of CO_2 in the water column, a known acid, and can explain the phenomenon of increased calcite preservation as the reduced acidity of ocean water.

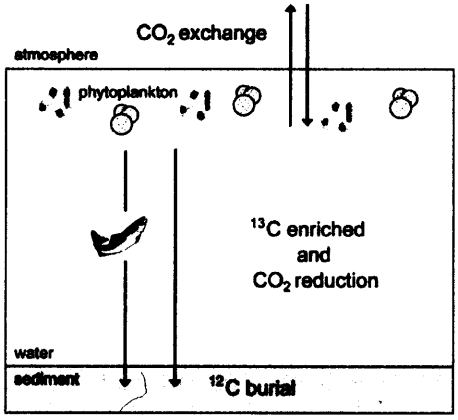


Figure 11.2 Diagram showing a simplified version of the carbon cycle for the ocean. As carbon burial increases, lower CO_2 reduces the acidity of the water column facilitating greater calcite preservation. Preferential take-up of ^{12}C by living organisms causes the $\delta^{13}C$ of sea water to increase. Levels of atmospheric CO_2 also decrease in equilibrium with the ocean.

The decreased CO_2 in the water column also has the effect of removing CO_2 from the atmosphere because, over long timescales, the ocean-atmosphere system is in equilibrium. Independent proxies for atmospheric CO_2 do indeed show a decrease in levels over this interval. Pagani et al. (1999) produced a record of surface water CO_2 (fig. 11.3) obtained from carbon alkenones in marine sediments, based on the principle that fractionation during plankton photosynthesis is largely controlled by CO_2 in sea water. Their record shows significantly low levels during the Monterey Carbon Excursion, which is consistent with our record of increased calcite

preservation at this time but can not explain global warming with our current understanding of CO_2 as a greenhouse gas.

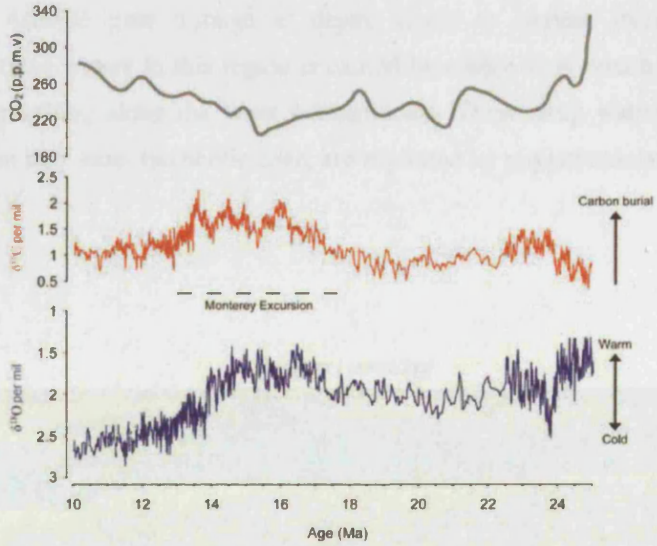


Figure 11.3 Atmospheric CO_2 concentrations for the Early-Middle Miocene as estimated from alkenones (Pagani et al. 1999, redrawn from Flower 1999), against global $\delta^{13}C$ and $\delta^{18}O$ (Zachos et al. 2001). Lower concentrations accompany the Monterey Carbon Isotope Excursion and the warming of the Miocene Climatic Optimum.

11.6 Infaunal Increase and Global Cooling

A major palaeoecological shift at this site is recorded at approximately 16.2 Ma as a dramatic increase in the calcareous benthic foraminiferal infaunal morphogroup and a decrease in diversity (fig. 5.17, line A). The infaunal morphogroup has been found by many authors to indicate lower oxygen levels (e.g. Corliss 1991; Kaiho 1994; Berhard et al. 1997; Jorissen et al. 1995; Jorissen 1999; Gooday 2003), and lower oxygen conditions would also be expected to cause reduction in diversity.

Low oxygen levels at the middle bathyal depths estimated for this horizon (see section 11.2 above) are likely to be caused by an expansion of the oxygen minimum zone (OMZ), linked to greater surface water productivity and/or sea level fall. Figure 11.4 shows a depth transect for the

modern South Atlantic Ocean offshore western Africa. A clear OMZ can be seen between about 50 – 1000 m depth, which is caused by increased productivity in the surface waters. As the organic matter settles from the water column it is consumed by biological organisms which thrive, using large quantities of oxygen during respiration. As better ventilated bottom waters from the North Atlantic pass through at depth, levels in oxygen increase. The greater productivity in surface waters in this region is caused by trade-winds which blow from east to west and cause upwelling along the West African coast. These deep waters carry with them nutrients and, when they enter the photic zone, are exploited by phytoplankton blooms (Ufkes et al. 2000).

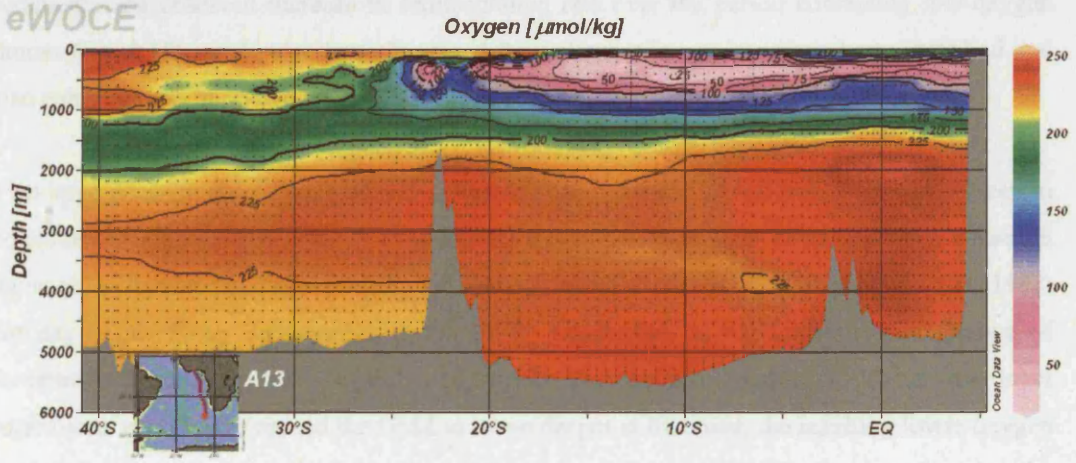


Figure 11.4 Oceanic oxygen concentrations of today's southeastern Atlantic Ocean (north-south transect from equatorial West Africa to 40°S). A prominent zone of low oxygen (OMZ) occurs at low latitudes from approximately 50 – 1000 m depth (Electronic Atlas of WOCE Data www.ewoce.org).

The driving force behind trade winds is the strength and position of the polar front, which has been found to increase in strength and move equatorward during glacial phases in the Pleistocene due to greater temperature differential between the poles and equator (Stuut et al. 2002). The coincidence of global cooling (increased $\delta^{18}O$) and increased low-oxygen infaunal species at around 16.2 Ma in this section (fig. 5.17, line A) may potentially be linked to an increase in wind strength off the coast of West Africa and the associated expansion of the OMZ. The increased $\delta^{18}O$ may be reflecting this raised colder nutrient-rich bottom-water. Global cooling at around

this period is recorded in both the Zachos et al. (2001) global composite, and the Barron and Keller (1982) global deep-sea dissolution horizon at around 16 – 15 Ma (indicating greater bottom-current strength driven by polar cooling). This hypothesis could be tested by looking for increased aeolian sand grains during this interval, which has been used as a measure of wind strength (Stuut et al. 2002). Although Holbourn et al. (2004) suggested the record of increased $\delta^{18}O$ between 16 – 15 Ma (at the western Australian margin) was not caused by polar cooling, this scenario does seem more likely based on the evidence above. In addition, two major sea level falls (fig. 5.18, TB2.3 and TB2.2) around the same time may well be linked to an increase in terrestrially-derived organic matter from increased weathering of larger continental areas, which is also known to aid productivity (Fontanier et al. 2005) and may have acted as a strengthening force. This could be tested by running total organic carbon (TOC) analysis of the sediment. The observed increase in sedimentation rate over the period containing low-oxygen faunas (fig. 5.18) would also have increased the volume of organic carbon being supplied and also enhanced productivity.

Two large peaks in absolute abundance at approximately 16 and 15 Ma (fig. 5.18) can be seen to coincide with TB2.3 and TB2.2. It is known that reduced oxygen conditions can cause an increase in faunal density, especially of infaunal species (Alve 1995; Bernhard et al. 1997; Gooday et al. 2000; Schumacher et al. 2007), which can be explained by an absence of foraminiferal predators due to the inhospitable low oxygen conditions. These sea level regressions would have caused the OMZ to move deeper at this time, the resulting lower oxygen potentially explaining increased abundance. This runs counter-intuitive, as transgressions are the cause of maximum flooding surfaces which typically exhibit greater concentrations of foraminifera due to decreased sedimentation rate. The low-oxygen hypothesis can satisfactorily explain TB2.4, but TB2.3 shows an increase in both infaunal *and* epifaunal species and therefore cannot be linked to low oxygen. When examining figure 5.18 in closer detail however, TB2.3 actually predates the abundance maximum by a small amount and it is the high sea level that coincides. TB2.3 may therefore be the result of a maximum flooding surface. The age model for this section is however not accurate enough to fully resolve this issue.

A detailed study of Recent foraminifera from an OMZ transect off the Pakistan continental margin (Arabian Sea) by Schumacher et al. (2007) found that faunal densities increase and diversities decrease as oxygen levels fall. They found that, in the lower part of the OMZ (500 – 1200 m) species of *Uvigerina*, *Bulimina*, *Reophax* and *Ammodiscus* dominate, and in the upper part of the OMZ (150 – 500 m) *Uvigerina*, *Bolivina*, *Bulimina* and *Ammodiscus* dominate.

Interestingly they also found species in the upper part to be of an endemic nature. The dominating taxa in this study over the oxygen minimum interval are *Bulimina elongata*, *Uvigerina* aff. *carapitana*, *Brizalina* aff. *barbata* and *Brizalina alazanensis*, of which *Uvigerina* aff. *carapitana* and *Brizalina* aff. *barbata* are of an endemic nature suggesting the possibility of a dramatically increased OMZ over this interval.

An increase in *Glomospira* spp. at approximately 15.2 Ma (fig. 5.17, line B) is associated with a drop in calcareous percentage but continued low diversity. The species *G. charoides* and *G. gordialis* are known to be tolerant to unusual environmental conditions in certain circumstances (see section 11.3 above), such as the high organic matter flux '*Glomospira* facies' of Kaminski and Gradstein (2005). *Glomospira* is also one of the few agglutinated taxa to persist through the level of low oxygen (approximately 16 – 15 Ma, fig. 5.17) and therefore may well indicate a continued OMZ expansion at this time.

11.7 Conclusions

1. Benthic foraminiferal assemblages, defined with the help of morphogroup analysis and Correspondence Analysis, reveal a changing fauna affected by three tiers of forcing parameters: sedimentology and energy levels in the benthic boundary layer; oxygen fluctuations and changes to surface water productivity; ocean chemistry and shifts in CCD through time. The majority of the section contains shales representing a relatively stable environment with turbiditic sedimentation rates ranging from 5 – 20 cm/kyr. Within this interval a dramatic shift is seen from epifaunal-dominated to shallow infaunal-dominated benthic foraminifera, at approximately 15.5 Ma. Palaeobathymetric estimates reveal a palaeodepth of around 1000 m (middle to lower bathyal) at this time.

2. A good record of benthic $\delta^{18}O$ and $\delta^{13}C$ isotopes has been obtained from the Miocene section of Plutao-1 (depths 2800 – 3420 m) which, when plotted against time, shows a clear fit to the global average trends of Zachos et al. (2001). The record reveals increasing levels of $\delta^{13}C$ from approximately 20 – 16 Ma leading into the early part of the well-documented Monterey Carbon Isotope Excursion of Vincent and Berger (1985). Records of $\delta^{18}O$ show general warming from approximately 20 – 16 Ma, with a cooling phase from 16 Ma coinciding with the Monterey Excursion.

3. Increasing $\delta^{13}C$ over this interval is mirrored by increasing percentage of calcareous foraminifera. This striking relationship can be explained by reduced oceanic acidity, related to increased carbon burial as recorded by lower levels of the organically-preferred lighter ^{12}C. As greater carbon burial ensued, CO_2 in seawater was also reduced. This has been recorded in independent records of atmospheric CO_2, which show reduced levels over this interval (Pagani et al. 1999).

4. A dramatic increase in the infaunal morphogroup at around 16.2 Ma records an expansion of the OMZ and the transition from well-oxygenated faunas to lower-oxygen faunas. This transition is coincident with cooling (as recorded by increased $\delta^{18}O$), and is argued to be related to greater wind strength in this region (comparable to the modern trade-winds) caused by a stronger polar front. The associated upwelling resulting from offshore winds would have increased surface water productivity and driven an expansion of the OMZ.

5. In addition to stronger winds, two large falls in sea level (TB2.3 and TB2.4) at around 16 and 15 Ma would have increased the amount of weathering due to the greater exposure of land, which in turn would have increased organic carbon supply to the sea floor. The greater sedimentation rate recorded for this interval would also have increased organic carbon supply.

6. Two large peaks in faunal density (abundance per 100 g of sediment) are recorded at around 16.2 and 15 Ma. The younger peak is coincident with a sea level fall (TB2.4), and may therefore be the result of further movement into the OMZ and a reduction in the number of predators able to survive in the low-oxygen conditions. The older peak in faunal density occurs shortly after TB2.3 and may be the result of a maximum flooding surface and reduced sedimentation rate.

CHAPTER 12 – DISCUSSION OF OLIGOCENE PALAEOENVIRONMENT AND PALAEOCEANOGRAPHY

Upper Oligocene sections, as determined by calcareous nannofossils, occur in all three wells Plutao-1, Saturno-1 and Venus-1 (fig. 9.1). The vast majority of faunas over this stratigraphic interval are agglutinated in nature (figs 5.4, 7.1 and 8.1), and reveal the most taxonomically diverse deep-sea Oligocene fauna yet described with over 100 species. These results extend the known stratigraphic ranges (last occurrences) of *Reticulophragmium amplectens* into the Oligocene and Miocene in the Atlantic, and possibly also of *Paratrochamminoides gorayskii*, *Paratrochamminoides olszewskii*, *Trochamminoides* aff. *proteus*, *Trochamminoides subcoronatus*, *Haplophragmoides horridus* and *Haplophragmoides walteri*, although some reworking is documented with these species. Results also extend the known first occurrences of *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana* into the Oligocene.

12.1 Caving and Reworking

Some caving (down-hole contamination of sediment) occurs in the wells and is due to limitations in ditch cutting sample collection. Occasional microfossils from higher levels within the Miocene appear in the studied samples as specimens with a different wall structure (the amount of silicification increases with depth of burial). This phenomenon can be seen in figure 12.1, where the white colour of the poorly-silicified specimens from the upper section of Plutao-1 (3630-3790 m) occur in deeper samples (3800-4010 m) where higher silicification has caused the *in situ* foraminiferal test walls to become more brownish in colour.

Reworking (re-deposition of stratigraphically older fossils) also occurs and can be seen in figure 12.1, which shows the percentage of highly-silicified (green-coloured) specimens (believed to be partially Eocene in age) occurring in most of the studied samples. Reworking of stratigraphically older fossils would be expected as the onset of deposition of the Congo Fan occurs very close to the base of this section (see Chapter 3), where Upper Cretaceous to Middle Eocene sediments extend only about 200 m below the studied interval. The Congo Fan today is fed by the Congo Canyon which stretches from the shelf, near the mouth of the Congo River, to the lower Slope at around 2000 m water depth (Babonneau et al. 2002). It then reduces significantly in relief as it continues all the way to the abyssal plain (over 4000 m depth). The present day canyon cuts into the underlying sediments by between 1300 m (at the upper Slope) to 150 m (at the lower Slope).

Cretaceous or Palaeocene species are not seen in the samples (Appendix 1 – 4), but there are occurrences of small well-silicified *H. walteri*, early *R. amplectens*, *R. intermedium*, *Recurvoides* spp. and *Caudammina* spp., which may be expected from the Eocene. These are probably reworked from older sediments due to their different wall structure, but the extent of reworking is only from the Eocene at this location.

In all three wells numerous calcareous specimens occur only at certain depths, and are generally poorly preserved, dominated by robust forms, and associated with submarine channel horizons (see Chapter 10). These calcareous forms are interpreted as transported down-slope and, although contemporaneous, not *in situ*.

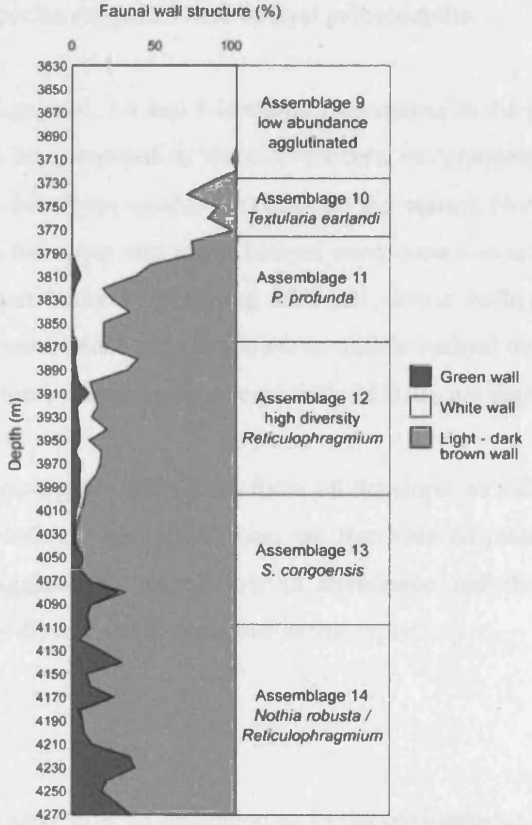


Figure 12.1 Changes in faunal wall structure with depth for the Oligocene section of Plutao-1. Green wall represents well-silicified cement and can be viewed as percentage of reworked specimens from older strata. White wall represents poorly silicified cement *in situ* at the top of section, with caved specimens at intermediate depths.

12.2 Palaeobathymetry

The palaeobathymetry of the section is estimated to be middle bathyal (600 – 1000 m) to lower bathyal (1000 – 2000 m) based on morphogroup analysis and comparisons with living species. Caution is needed when analysing palaeobathymetry in this environmental setting as deep-sea fans are turbidite-dominated and therefore transportation of material from higher up the slope may be common. The Oligocene sections that are generally low in sand content (see fig. 9.1) suggest a minimal input of transported larger particles including foraminifera, and upper slope / shelfal species are indeed not found. There are four bathymetrically useful species in the samples that are also known from the Recent. These are *L. lituiformis* (upper – lower bathyal), *A. clavata* (upper bathyal – abyssal), *H. guttifera* (middle – lower bathyal) and *R. rotundidorsatum* (lower bathyal – abyssal), as recorded by Brady (1884) in the *Challenger Report* (see Jones 1994). The co-occurrence of these species suggests lower bathyal palaeodepths.

Morphogroup analysis (figs 5.14, 7.4 and 8.4) shows fluctuations in the gross-morphology of the assemblages, which can be compared to those in modern environments. Jones and Charnock (1985) synthesised such data from various localities on the eastern North Atlantic margin. The major variation between the upper and lower bathyal zone occurs in morphogroup M1 (tubular suspension feeders); upper bathyal containing 50% M1, lower bathyal 70% M1. Variations within this range can be seen, which suggests lower to middle bathyal depths. It remains a strong possibility however that these morphogroups (especially M1) are not depth-dependent.

Environments on the abyssal plain differ from those on the slope, as recorded by Hart (1988) in the study of Miocene benthic foraminifera from the Bermuda Abyssal Plain (Site 603). Hart reports only a sparse agglutinated fauna, low in abundance and diversity, and contrasting markedly from the highly diverse fauna described in this report.

12.3 Palaeoecology

Foraminifera can at best only give an indication as to the environment in which they lived and died (see Van der Zwaan et al. 1999). There are significant differences in the composition of living and dead assemblages recorded for example in the Adriatic Sea (Jorissen et al. 1992), the Weddell Sea (Murray and Pudsey 2004), and on the West African continental slope (Licari and Mackensen 2005). Licari and Mackensen (2005) conclude however that in the West African

setting, these differences are not great enough to hide ecological information and suggest that dead assemblages can be used faithfully to reconstruct primary-productivity changes.

The almost entirely agglutinated nature of the studied Oligocene assemblages is striking. This cannot be explained by deposition below the global CCD average, as palaeobathymetric estimates (see section 12.2 above) point to at most lower bathyal depths (maximum 2000 m). There are rare calcareous benthics present in some of the samples (see Appendix 1 – 4), although the majority of the samples are composed of entirely agglutinated forms. The faunas are not dissimilar to the '*Rhabdammina*' faunas first described from 'flysch' deposits of the Alpine-Carpathian orogeny in Europe (see Kaminski and Gradstein 2005; Kender et al. 2005), and also reported from other localities around the world from later-Cretaceous to Recent sediments (Jones 2006). These faunas seem to be relatively independent of water depth and are probably not the result of later dissolution of an original calcareous component (see Chapter 10, section 10.2). They all occur in rapidly deposited turbiditic shale environments however. This phenomenon is not unexpected in this setting (see for example similar findings in the Forties Field, North Sea) where it has been suggested that the oxidation of rapidly deposited organic matter in early diagenesis can release calcareous-dissolving acids (Jones 1999, 2006). The phenomenon may, however, simply be due to high sedimentation rates and low oxygen conditions in which agglutinated forms are able to survive where more specialised and highly adapted calcareous forms cannot. This seems unlikely in the light of fully calcareous faunas described from shallow (only several hundred metres depth) Miocene canyon/fan environments from Spain (Rogerson et al. 2006).

Near the bottom of the studied sections of Plutao-1 and Venus-1, and Assemblages 9 and 10 of Saturno-1 (see fig. 9.1) the faunas show low diversity and abundance, probably due to high sand content, and the darker colouration of Plutao-1 (possibly indicating high organic carbon and lower oxygen conditions). The high occurrence of *Nothia robusta* also suggests high energy (Kaminski and Gradstein 2005). Increasing diversity and abundance up the section indicates more favourable conditions (i.e., lower energy, lower organic flux and better oxygenated waters), and this is also supported by less domination of morphogroups by any one component (figs 5.14, 7.4 and 8.4). In Saturno-1 the following interval (Assemblages 7 and 8) is more expanded than that of Plutao-1, in large part because of the more oblique angle of drilling to bedding-plane (see line of well against seismic survey, fig. 9.2).

The following intervals in Plutao-1 and Saturno-1 show an increase in morphogroup M4b (the '*Scherochorella* Event' – see below) along with a decrease in diversity and increase in abundance, probably relating to lowering oxygen levels caused by high productivity and the resulting high organic carbon flux. The TROX-model, first proposed by Jorissen et al. (1995), links deep-infaunal foraminifera with low oxygen conditions due to high organic carbon flux. Preece et al. (1999) observed a correlation between agglutinated foraminiferal morphogroups and organic carbon off Cabinda, West Africa, and it is therefore probable that *S. congoensis* is a high productivity indicator. The greater abundance of *N. robusta* over this interval supports this interpretation, as this species usually occurs in levels of low diversity in all wells and can be regarded as an opportunistic species. The possibility that the interval represents dominating hemipelagic shale as opposed to inter-turbiditic shale cannot be ignored, since Jones (1999) records hemipelagic shales in the North Sea as having higher proportions of the infaunal morphogroup. One would however expect an increase in diversity with hemipelagic shale, but these records show a decrease.

The diversity increase through the following intervals (Assemblage 5 – Saturno-1, Assemblages 11 and 12 – Plutao-1, Assemblages 7 and 8 – Venus-1) probably reflects a return to more stable and favourable conditions, indicated by the low sand contents and high abundances. The decrease in the tubular morphogroup M1 and high proportions of *Portatrochammina profunda* (assemblage 4) indicates perhaps a shallowing of environment (to middle bathyal depths), which may be expected with the very high sedimentation rates (in the region of 120 m/my), or simply a shoaling of the oxygen minimum zone. The distribution of *P. profunda* and its occasional dominance is not well understood, as it occurs in both high and low diversity assemblages. It may be responding to increased organic carbon, in addition to being tolerant of more stressed conditions.

The following *Textularia earlandi* assemblages in Plutao-1 and Venus-1 are similar in their content of this species, coupled with continued high diversity. Although *T. earlandi* fits into the infaunal morphogroup, the associated assemblages with which this species occurs (and does not always dominate) are not indicative of low oxygen. Several studies have found that an infaunal component (in a submarine fan setting) actually indicates optimal conditions for faunal growth (Smith and Gallagher 2003; Koho et al. 2007), and these assemblages may therefore represent a time of low energy, high organic supply, and well-ventilated bottom waters, and perhaps an interval of dominating hemipelagic shales (Jones 1999).

Conditions probably became more stressed after these intervals in all three wells, indicated by lowering diversity and abundance, and increasing sand and morphogroup M1.

12.4 Palaeoceanographic Context

Throughout the Late Oligocene sea levels were fluctuating intensively (fig. 12.2) after a major sea-level fall at the Early / Late Oligocene boundary (Haq et al. 1987; Miller et al. 2005; Pekar et al. 2006). Kaiho (1991) and Kaiho and Hasegawa (1994) reported falling bottom-water dissolved oxygen levels in the South Atlantic at this time based on benthic foraminiferal morphological proxies, and postulated that this was caused by slower deep-water circulation in response to elevated temperatures. The oxygen isotope record from the Oligocene has been studied in detail by Pekar et al. (2006) and generally agrees with Kaiho's interpretation. Pekar et al. also found bottom waters to be warmer in the Oligocene in the low latitude Atlantic and Pacific Oceans. However, they also reported a significant deviation in the isotopic record in the Upper Oligocene between the Antarctic and the lower latitudes, suggesting that a large glaciation occurred in the latest Oligocene (26-23Ma), and that transport of these cold waters to the north was prevented owing to a stifled proto-AABW (Antarctic Bottom Water). Prebble et al. (2006) and Roberts et al. (2003) found miospore floras in the Antarctic Ross Sea that indicate cold temperatures (mean summer 5°C) by the Late Oligocene, whilst Villa and Persico (2005) and Persico and Villa (2004) found nannofossil assemblages from sites in the Southern Ocean (Maud Rise and Kerguelen Plateau) indicating cold waters until the latest Oligocene, when warmer-water taxa began to dominate. The proposed Oligocene glaciation would have been significantly warmer than that of today. Mutti et al. (2005) recorded low $\delta^{18}O$ values in the Upper Oligocene from Site 999 in the Columbia Basin, with increasing values (probably cooling) by the latest Oligocene. Miller et al. (1991) also found decreasing bottom water $\delta^{18}O$ values in the latter part of the Late Oligocene from sites 522 and 529 in the southeast Atlantic. This is in agreement with the Zachos et al. (2001) averaged global $\delta^{18}O$ levels for this period.

12.5 *Scherochorella* Event

The large excursion in the deep-infaunal morphogroup M4b (termed here the '*Scherochorella*' event) in Assemblage 13 of Plutao-1 and Assemblage 6 of Saturno-1 (fig. 9.1) is regarded as an ecological response to a change in oceanographic conditions. There is no reason to suggest that a change in sediment supply occurred, as the gamma logs, lithology and sand contents over this interval show no significant deviations.

Oligocene cooling and glaciation probably caused the strength of bottom currents in the Atlantic to increase, and could explain the generally low recovery of Oligocene sediments (due to bottom water erosion) from many sites in the Atlantic. Tucholke (1979) and Tucholke and Mountain (1986) synthesised data from western North Atlantic DSDP Sites and found major unconformities of Oligocene age, which they interpreted as erosional surfaces from strong deep-water flow. Similarly, none of the ODP sites drilled off West Africa during ODP Leg 159 recovered any sediment of Oligocene age, indicating that submarine erosion was not confined to the western Atlantic. This is in contrast to the slower warmer waters proposed by Kaiho (1991), but may indicate a fluctuation between the two scenarios.

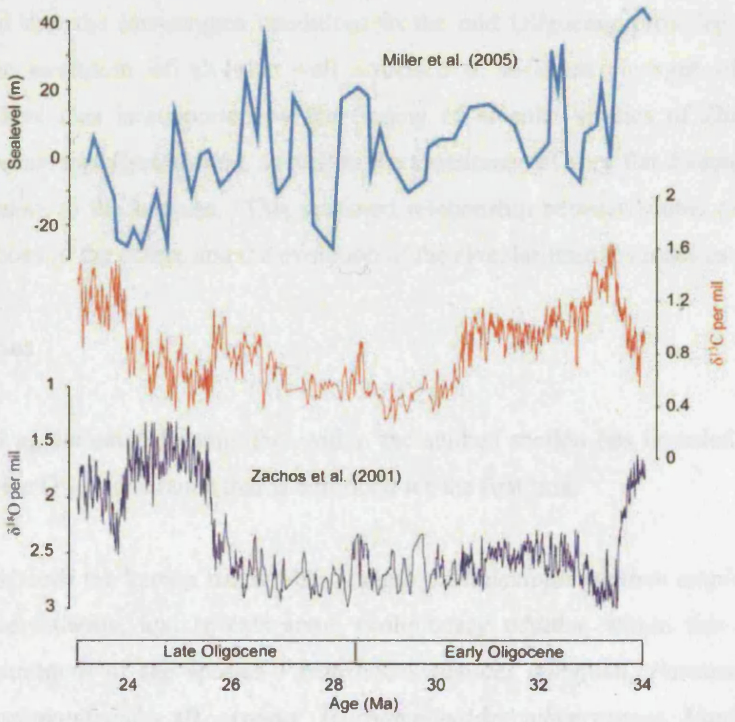


Figure 12.2 Global sealevel (Miller et al. 2005), benthic $\delta^{18}O$ and benthic $\delta^{13}C$ (Zachos et al. 2001) for the Oligocene. All curves are global composite averages.

Glacial conditions and cooling in the Southern Ocean during the late Oligocene (fig. 12.2) would have caused increased temperature differential between the poles and low latitudes.

Consequently, an increase in wind strength would be observed in the sub-tropics and temperate latitudes that would in turn lead to increased upwelling strength and elevated productivity offshore West Africa during the Late Oligocene. Carbon isotope records from DSDP sites in the Atlantic Ocean (Miller and Fairbanks 1985; Miller et al. 1991) show a broad minimum in $\delta^{13}C$ values, suggesting slower production of deep water and elevated nutrients in the Atlantic during the late Early Oligocene to early Late Oligocene (32 – 26 Ma) which is in agreement with the Kaiho (1991) proposal of slower deep-water circulation. During the mid-Oligocene, nutrient concentrations in Atlantic deep water were more similar to those of older deep water in the South Pacific today, which would have conspired to further increase productivity in the Atlantic upwelling zones. It is hypothesized therefore that the origin of the apparently low-oxygen '*Scherochorella* Event' may be linked to downward expansion of the oxygen minimum zone off West Africa, perhaps around the time of polar cooling and persistently low $\delta^{13}C$ (~ 27 Ma). It is also speculated that the low-oxygen conditions in the mid Oligocene provided a habitat that resulted in the evolution of alveolar wall structure in different lineages of agglutinated foraminifera. This idea is supported by the finding of alveolar species of *Discamminoides*, *Reticulophragmium* and *Cyclammina*, as well as the appearance of very flat discoidal forms such as *Spiropsammina*, in the samples. This proposed relationship between global climate change, dysoxic conditions in the ocean, and the evolution of the alveolar lineages requires further study.

12.6 Conclusions

Analysis of all agglutinated foraminifera within the studied section has revealed a unique and extremely diverse Oligocene fauna that is described for the first time.

1. This study extends the known stratigraphic ranges of *Reticulophragmium amplectens* into the Miocene in the Atlantic, and reveals some evolutionary oddities within this lineage. New Oligocene occurrences of the species *Paratrochamminoides gorayskii*, *Paratrochamminoides olszewskii*, *Trochamminoides* aff. *proteus*, *Trochamminoides subcoronatus*, *Haplophragmoides horridus* and *Haplophragmoides walteri* are also reported, species that are known from the Eocene at other localities. The oldest first occurrences of *Recurvoides azuaensis*, *Spiropsammina primula*, *Cyclammina* aff. *orbicularis*, *Discamminoides* sp. and *Glaphyrammina americana* as Oligocene is also recorded.

2. The deposition of the Congo Fan began in the Oligocene, and its inception coincides with the base of the studied section. Reworking has been detected from stratigraphically older sediments

(Eocene) but this is not extensive. Caving has been detected from stratigraphically younger sediments (Miocene) in the shallower samples.

3. Comparison of the fauna with equivalent living species (*Lituotuba lituiformis*, *Ammolagena clavata*, *Hormosina guttifera* and *Reticulophragmium rotundidorsatum*), and comparison with morphogroup changes with depth in modern and ancient settings, allows an estimate of middle to lower bathyal palaeodepths for the Oligocene stratigraphic section.

4. One faunal signal in the studied section cannot be explained by changing sedimentary influence alone, and is here termed the '*Scherochorella*' event. Over this interval a marked peak in the infaunal species *Scherochorella congoensis* is observed, along with a marked increase in the opportunistic species *Nothia robusta*. This is coupled with a decline in diversity and an increase in foraminiferal abundance. This is possibly a response to lowered oxygen conditions, driven by slower circulation of nutrient-rich proto-North Atlantic Deep Water during the mid-Oligocene, combined with stronger upwelling and expansion of the oxygen minimum zone caused by increased wind strength during a time of Antarctic glaciation. It is hypothesized that the late Oligocene evolution of "infaunal" and alveolar taxa was ultimately driven by the intensification of the oxygen minimum zones in subtropical upwelling areas.

CHAPTER 13 – SUMMARY

DECONSTRUCTING THE UPPER OLIGOCENE TO MIDDLE MIOCENE HISTORY OF THE CONGO FAN USING FORAMINIFERAL FAUNAS

13.1 Introduction

The Congo Fan is the distal component of the second largest delta system in the world, covering some 3.7 x 10^6 km^2 and draining most of central Africa through the Congo River and its associated tributaries. The Congo Fan is a terrigenous wedge largely built of Oligocene and Miocene sands and shales organised into thick sedimentary packages containing palaeocanyons, palaeochannels and overbank deposits (Anka and Séranne 2004; Babonneau et al. 2002; Lavier et al. 2001). These unique meandering palaeochannels contain sands that have proven high quality traps for migrating hydrocarbons. The Congo Fan has received significant scientific attention in recent years due in part to this interest from the oil industry. Our understanding of the distribution and response of micropalaeontological faunas from clastic submarine fan environments is not yet complete and has received relatively little study to date (see Lundquist et al. 1997; Jones 1999; Smith and Gallagher 2003; Dellamonica 2004; Fontanier et al. 2005; Jones et al. 2005; Jones 2006; Rogerson et al. 2006; Koho et al. 2007).

Throughout the Late Oligocene sea levels were intensively fluctuating after a major sea level fall at the Early / Late Oligocene boundary (Haq et al. 1987). Kaiho (1991) postulated slower deep-water circulation in response to elevated temperatures after reporting falling bottom-water dissolved oxygen levels in the South Atlantic based on benthic foraminiferal morphological proxies. Pekar et al. (2006) also found bottom waters to be warmer in the Oligocene in the low latitude Atlantic and Pacific Oceans, with a significant deviation in the isotopic record in the Upper Oligocene between the Antarctic and the lower latitudes suggesting that a large glaciation occurred in the latest Oligocene (26-23Ma), with transport of these cold waters to the north somewhat stifled. Deep-sea hiatuses from this period (Tucholke and Mountain 1986) suggest accelerated deep currents, but not from a southern source.

The Early-Middle Miocene represents a transitional phase between the Paleogene climatic high and the 'icehouse' climate of the Neogene. The Early Miocene witnessed a series of fluctuating Antarctic glacial and interglacial episodes which culminated in the warmest period of the Neogene around the early/middle Miocene boundary, before a significant cooling phase and the

final transition into the cold icehouse world at around 14 Ma (Miller et al. 1991; Flower et al. 1997).

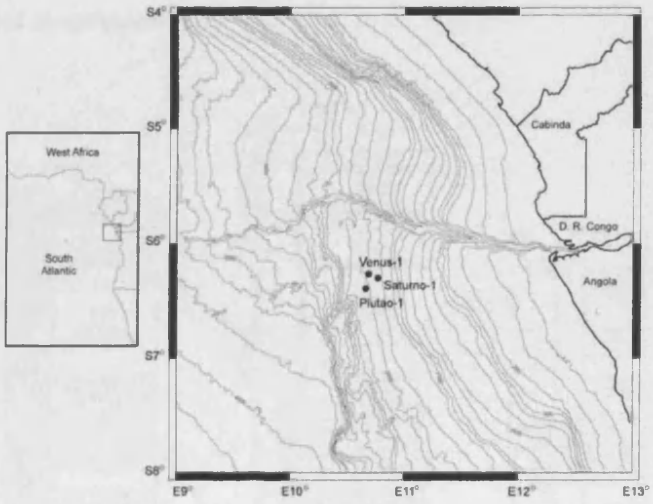


Figure 13.1 Location of the Congo Fan and wells analysed in this study. The wells penetrated up to 3 km beneath the sea floor.

13.2 Methods

Over 450 rock-cuttings and sidewall core samples from three wells have been analysed for planktonic and benthic foraminifera from the Upper Oligocene to Middle Miocene of the deep-sea Congo Fan (fig. 13.1). Biostratigraphic analysis of calcareous nannofossils (ExxonMobil) and planktonic foraminifera have been correlated to the Lourens et al. (2004) timescale. Absolute abundances and statistical diversity measures have been constructed by statistical counting of samples and using Fisher's α diversity index. Assemblage definition is based on foraminiferal changes, and analysed with Correspondence Analysis and 'morphogroup' analysis. A full taxonomic study of the largely benthic foraminifera has been carried out by comparisons with the literature. Due to the scarcity of calcareous benthic foraminifera in some samples, oxygen and carbon isotopes were obtained from the Miocene only using *Cibicidoides* spp. (*C. mundulus* and *C. pachyderma* were preferentially used where available); 2-5 specimens > 250 μm were taken where possible. Crushed specimens were then immersed in 3 % hydrogen peroxide for 30 min, ultrasonicated in methanol for 15 s, excess residue and liquid removed, and dried at 45 °C. Stable isotope analysis was conducted using a ThermoFinnigan MAT 252 and coupled carbonate preparation device at Cardiff University, with an external reproducibility of $\leq$ 0.08 ‰ for $\delta^{18}O$

and reported on the VPDB scale. Values of $\delta^{18}O$ recorded from *Cibicidoides* spp. have been adjusted by +0.64 ‰ to align them with equilibrium calcification at given temperature and $\delta^{18}O_{sw}$ (Shackleton 1974). Sedimentological data was obtained from rock-cutting analysis, wireline gamma-ray logs, and seismic profiles.

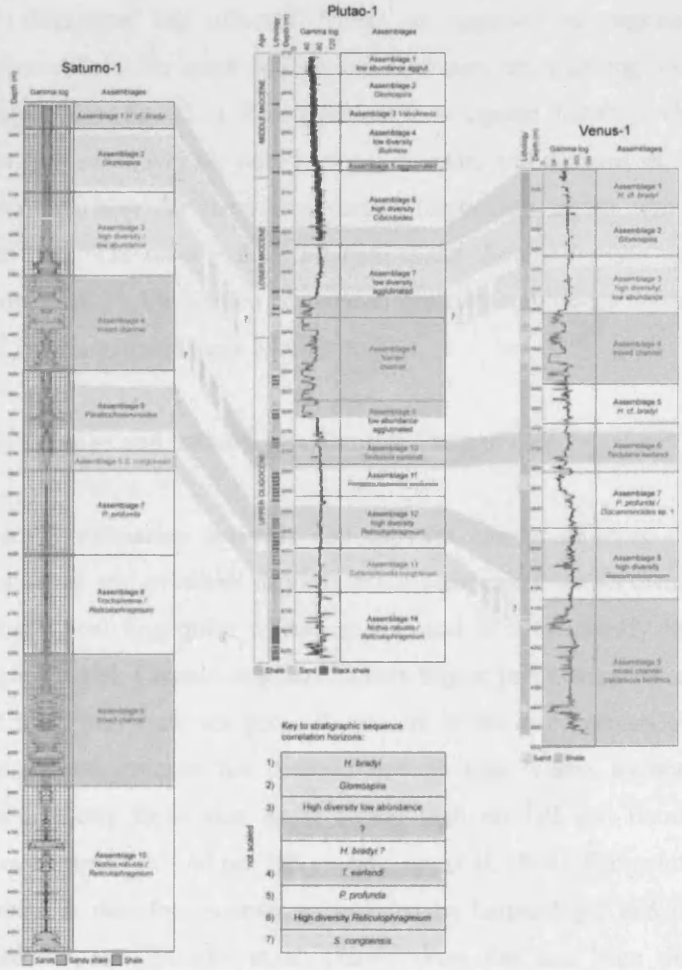


Figure 13.2 Benthic zonation for the analysed wells based on assemblage data. Sedimentologically-disrupted horizons (grey) are not used.

13.3 Biostratigraphy and Constructing Benthic Zonations

Biostratigraphy of West African margin oceanic deposits is challenging due largely to the dominant eutrophic upwelling conditions causing an environment inhospitable for the calcareous planktonic organisms traditionally used in biostratigraphy. Planktonic foraminifera and

calcareous nannofossils are rare in the studied sections, and have been used when present to constrain the age. Isotopic analysis has also helped tighten the age/depth model for the Miocene with satisfactory results. The Oligocene consists of almost entirely agglutinated benthic foraminiferal faunas with sparse nannofossils constraining the age to Upper Oligocene. Benthic assemblages have been designated and analysed in order to determine the extent to which local sedimentological disruption has affected faunas as opposed to regionally synchronous oceanographic 'events', with the result of several assemblage zones having been defined for use as chronostratigraphic ties (fig. 13.2). It is important to recognise that these chronostratigraphic events, although time-correlative, are only regional in scale, and analysis of further material is necessary to determine how far the signal carries (especially higher and lower along the palaeobathymetric line). The most striking of these is the '*Scherochorella*' event (intra-Upper Oligocene), a short stratigraphic section of reduced diversity agglutinated fauna dominated by the low-oxygen *S. congoensis* and large *N. robusta.*

13.4 Sedimentary Change and Influence on Benthic Faunas

On the largest scale, submarine channels and canyons consist of three main architectural elements; channel, levee and overbank deposits. Each component has its own sedimentological and micropalaeontological fingerprint which can be used to help identify the element in the geologic record after burial. Channel deposits contain higher proportions of sand and gravel as energy levels are high. Sands are not generally present in the more distant overbank deposits. Channel morphology and structure has changed through time. Today sediment is transported down channel as turbidity flows that occur during high rainfall and flooding, documented offshore Angola as occurring at ~ 60 per 100 yrs (Heezen et al. 1964). Sedimentation is relatively low and the channel is therefore erosive, surrounded by hemipelagic and overbank deposits rather than stacked levees. Broucke et al. (2004) show this has been the case since the Burdigalian-Langhian (20-13 Ma), where channels are generally isolated within a hemipelagic background. Before this time however, in the Chattian (28-23 Ma), sedimentation was more rapid and channels are found within a complex of levee turbidites. This is indeed the pattern observed in the material analysed in this study.

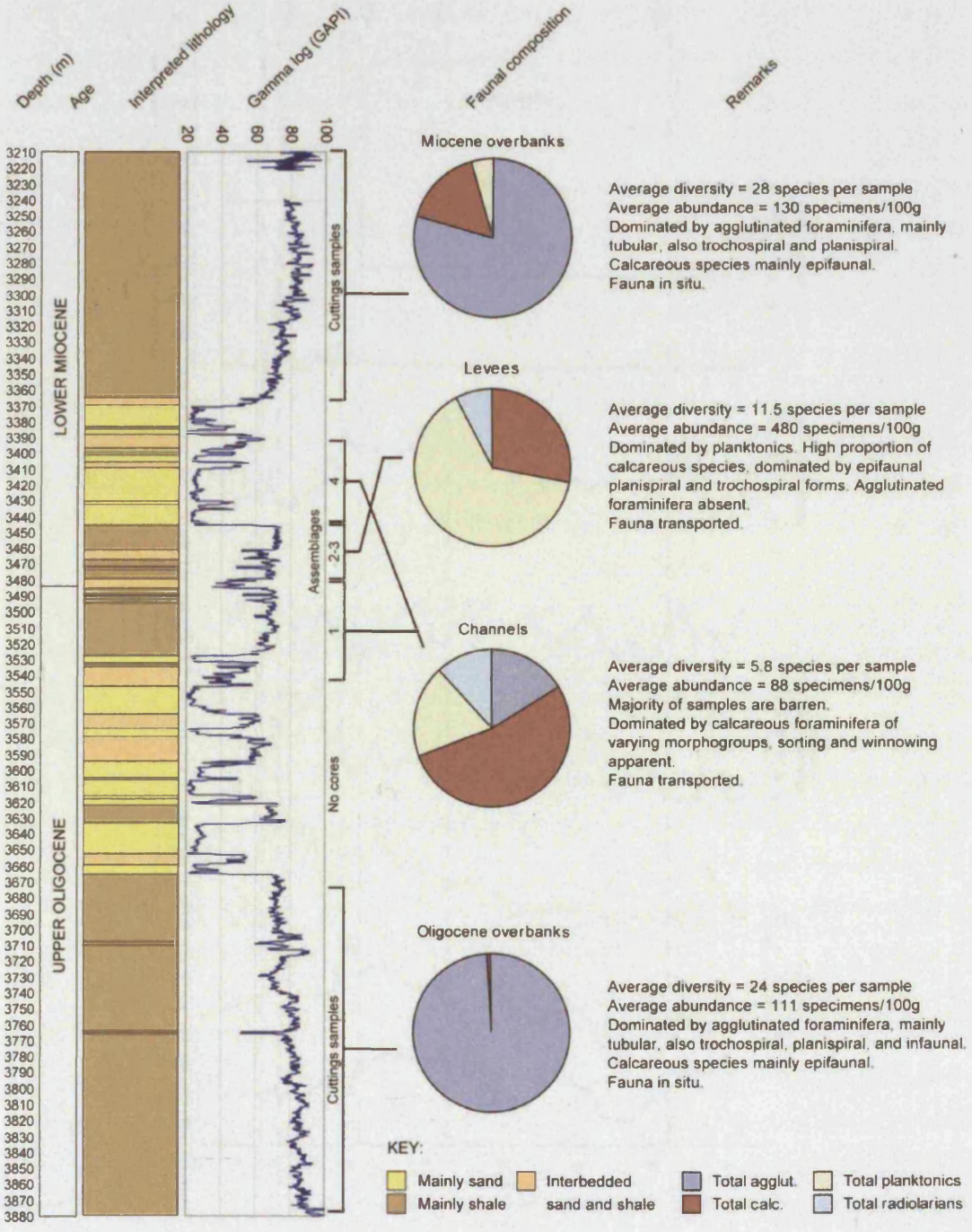


Figure 13.3 Summary of architectural elements from the Oligo-Miocene of the Congo Fan (Angola), showing the averaged faunal compositions for channel, levee, and overbank deposits.

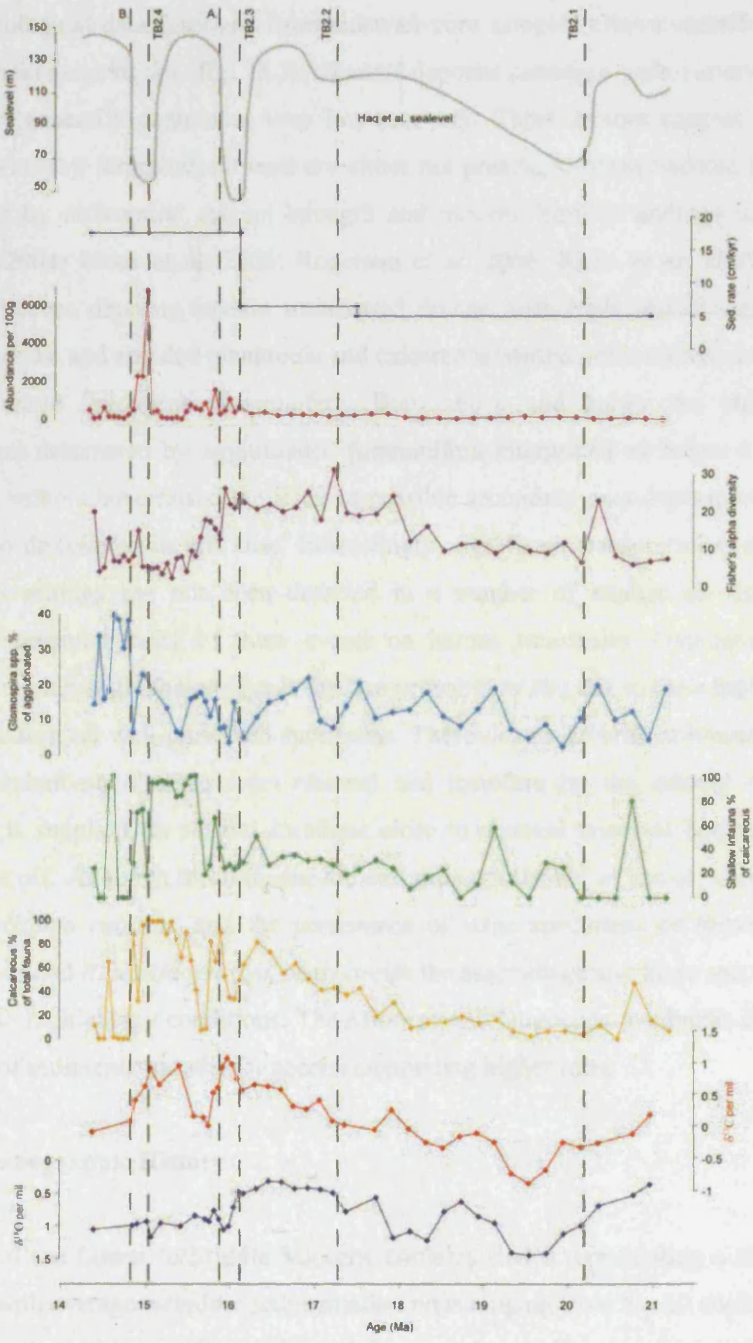


Figure 13.4 Graphs showing absolute faunal abundance, diversity, faunal characteristics, sedimentation rate and global sea level (Haq et al. 1987) against time and isotopic data. Vertical dashed lines mark the locations of the third-order sequence boundaries of Haq et al. (TB2.1 to TB2.4). Line **A** marks the onset of infaunal increase, diversity decrease and $\delta^{18}O$ increase. Line **B** marks the increase in *Glomospira* spp. and the decrease in calcareous content.

Micropalaeontological data retrieved from sidewall core samples allows identification of both levee and channel associations (fig. 13.3). Channel deposits contain a wide variety of faunas and sedimentology, generally containing very low recovery. These factors suggest a high energy environment whereby foraminiferal tests are either not present, or have become strongly sorted and winnowed by differential current strength and motion. Similar findings in other studies (Dellamonica 2004; Jones et al. 2005; Rogerson et al. 2006; Koho et al. 2007) support this interpretation. Levee deposits contain transported faunas, with high abundances and medium diversities of robust and abraded planktonic and calcareous benthic foraminifera and the presence of some reworked Paleogene foraminifera. Both above and below the channel sections assemblages are dominated by agglutinated foraminifera interpreted as below a locally raised CCD. Several authors have raised the issue of possible secondary post-depositional dissolution, but this can be discounted in this case. Interestingly, significant transportation of foraminifera within canyon settings has not been detected in a number of studies on Recent deposits, indicating the potential rarity of these events on human timescales. Overbank deposits are composed of varying agglutinated faunas that are probably *in situ* due to their high diversity and content of non-abraded well-preserved specimens. These faunas do change however, and this is probably dependent on distance from channel and therefore on the amount of energy and sediment that is supplied. In several locations close to channel horizons both abundance and diversity drops off. Although these faunas are still all agglutinated in nature, dominance by the large species *Nothia robusta*, and the persistence of large specimens of *Reticulophragmium rotundidorsatum* and *R. acutidorsatum*, characterise the assemblage and these species may be the most tolerant to high energy conditions. The Miocene and Oligocene overbanks differ primarily in their speed of sedimentation, the Oligocene comprising higher rates.

13.5 Palaeoceanographic History

The majority of the Lower to Middle Miocene contains shales representing a relatively stable environment, with average turbiditic sedimentation rates ranging from 5 – 20 cm/kyr. Within this interval a dramatic shift is seen from epifaunal-dominated to shallow infaunal-dominated benthic foraminifera at approximately 15.5 Ma (fig. 13.4). Palaeobathymetric estimates reveal a palaeodepth of around 1000 m (middle to lower bathyal) at this location. A good record of benthic $\delta^{18}O$ and $\delta^{13}C$ isotopes has been obtained from the Miocene which shows a clear fit to the global average trends of Zachos et al. (2001). The record reveals increasing levels of $\delta^{13}C$ from approximately 20 – 16 Ma, leading into the early part of the well-documented Monterey Carbon Isotope Excursion of Vincent and Berger (1985). Records of $\delta^{18}O$ show general warming

from approximately 20 – 16 Ma, with a cooling phase from 16 Ma coinciding with the Monterey Excursion. Increasing $\delta^{13}C$ over this interval is mirrored by increasing percentage of calcareous foraminifera. This striking relationship can be explained by reduced oceanic acidity, related to increased carbon burial as recorded by lower levels of the organically-preferred lighter ^{12}C. As greater carbon burial ensued, CO_2 in seawater also reduced. This has been recorded by independent records of atmospheric CO_2, showing reduced levels over this interval (Pagani et al. 1999 – from alkenones in marine sediments). A dramatic increase in the infaunal morphogroup at around 16.2 Ma records an expansion of the Oxygen Minimum Zone (OMZ) and the transition from well-oxygenated faunas to lower-oxygen faunas. This transition is coincident with cooling (as recorded by increased $\delta^{18}O$), and is argued to be related to greater wind strength in this region (comparable to the modern trade winds) caused by a stronger polar front. The associated upwelling resulting from offshore winds would have increased surface water productivity and driven an expansion of the OMZ. In addition, two large falls in sea level (TB2.3 and TB2.4) at around 16 and 15 Ma may have exacerbated this increased supply of organic carbon to the sea floor due to weathering of the greater exposed land surface, as is recorded in the higher sedimentation rates recorded for this interval. Two large peaks in faunal density are recorded at around 16.2 and 15 Ma. The younger peak is coincident with a sea level fall (TB2.4), and may therefore be the result of further movement into the OMZ and a reduction in the number of predators able to survive in the low-oxygen conditions. The older peak in faunal density occurs shortly after TB2.3 and may be the result of a maximum flooding surface and reduced sedimentation rate.

The large excursion in the deep-infaunal morphogroup termed the '*Scherochorella*' event is regarded as an ecological response to changes in oceanographic conditions. Oligocene cooling and glaciation probably caused the strength of bottom currents in the Atlantic to intermittently increase, and could explain the generally low recovery of Oligocene sediments (due to bottom water erosion) from many sites in the Atlantic (Tucholke 1979; Tucholke and Mountain 1986). Conversely, low $\delta^{13}C$ values during the majority of the Oligocene suggest that slow bottom-water circulation and higher levels of organic carbon was common. Glacial conditions and cooling in the Southern Ocean during the late Oligocene would have caused an increased temperature differential between the poles and low latitudes. Consequently, an increase in wind strength would be observed in the sub-tropics and temperate latitudes that would in turn lead to increased upwelling and elevated productivity offshore West Africa. The origin of the apparently low-oxygen '*Scherochorella*' event may be linked to downward expansion of the OMZ, perhaps

around the time of polar cooling and persistently low $\delta^{13}C$ values indicating increased nutrients in deep waters (~ 27 Ma).

13.6 Benthic Foraminiferal Evolution Through Time

Benthic foraminifera are on the whole long ranging organisms, and the majority of species over the studied interval are persistent and show little variation through time. The complex-walled agglutinated foraminifera (*Reticulophragmium*, *Cyclammina*, *Popovia*, *Discamminoides*, *Spiropsammina*) are an exception, and although precise evolution and extinction horizons cannot be identified due to the scarcity of these forms in the samples analysed, significant variation in this group is apparent. Seiglie and Baker (1983) found the Oligocene to Early Miocene period as the most evolutionarily prolific time for complex-walled agglutinates offshore West Africa. The evolution over the Miocene period has been examined before in terms of response to low oxygen environments in the Congo Fan (Preece et al. 1999). Although stratigraphically older sections need to be examined, the Oligocene section in this study shows several evolutionary oddities (representing an evolutionary explosion of sorts) within the *Reticulophragmium/Cyclammina* lineage, the appearance of *Spiropsammina primula* and the apparently endemic *Discamminoides* sp.1. The Oligocene black shales, with their greatly increased sedimentation rates and high organic carbon content, provide an environment that is certainly in-line with the low-oxygen hypothesis.

13.7 Conclusions

1. Analysis of three wells from the distal section of the Congo Fan reveals a Late Oligocene to Middle Miocene age based on biostratigraphic analysis, and contains abundant agglutinated and calcareous benthic foraminifera. Benthic foraminiferal assemblages have been used to construct a zonation which is able to chronostratigraphically tie the wells together in the absence of abundant planktonic foraminifera and calcareous nannofossils.

2. Foraminiferal and sedimentological analysis has allowed the characterisation of channel, levee and overbank deposits within the studied sections.

3. A positive excursion in the low-oxygen morphogroup during the intra-Late Oligocene (termed the '*Scherochorella*' event) has been linked to possible global cooling and the expansion of the oxygen minimum zone as a result of offshore wind increase and a stronger polar front.

4. A dramatic increase in the infaunal morphogroup at around 16.2 Ma records a Miocene expansion of the OMZ and the transition from well-oxygenated faunas to lower-oxygen faunas. This transition is coincident with cooling, and is argued to be related to greater wind strength in this region caused by a stronger polar front.

5. Two large peaks in faunal density are recorded at around 16.2 and 15 Ma. The younger peak is coincident with a sea level fall (TB2.4), and may therefore be the result of further movement into the OMZ. The older peak in faunal density occurs shortly after TB2.3 and may be the result of a maximum flooding surface and reduced sedimentation rate.

6. Increased evolution within the complex-walled agglutinated lineages during the Late Oligocene and Early Miocene has resulted in the documentation of several species not yet described, and may be related to lower-oxygen conditions.

13.8 Future Work

1. Stratigraphic resolution of the Oligocene would be greatly enhanced by studying further wells along a palaeodepth transect, in order to ascertain the extent of benthic foraminifera zone correlations. The analysis of further wells may also allow a more accurate dating for the palaeoceanographically important '*Scherochorella*' event. **2.** Analysis of Total Organic Carbon in each sample would provide valuable information relating to carbon flux and, potentially, estimation of oxygen minimum zone proximity. **3.** Analysis of good records of Upper Oligocene to Middle Miocene shelf sediments from other locations worldwide, especially in upwelling regions, would help in an attempt to correlate the '*Scherochorella*' event and mid-Miocene episodes of oxygen minimum zone expansion with possible global events relating to Antarctic cooling. **4.** Collection of greater numbers of alveolar walled agglutinated foraminifera from this location, and others worldwide, would help in uncovering a greater resolution of the evolutionary patterns within these lineages. **5.** Continue taxonomic work on the lesser-studied agglutinated foraminifera in an attempt to produce a global Neogene synthesis for this group.

CHAPTER 14 – TAXONOMY

The taxonomic work in this thesis has been compiled for the Miocene and Oligocene separately, with the aim of providing self-contained useable references for these two stratigraphical intervals. Over 220 species of foraminifera are described from the Early – Middle Miocene (115 agglutinated, 81 calcareous and 27 planktonic species), and over 130 agglutinated foraminifera are described from the Upper Oligocene. The majority of species have been illustrated using SEM photography. All descriptions (including occurrences) and photographs are from specimens recovered from Plutao-1 as this well had the highest and longest stratigraphical recovery. Venus-1 and Saturno-1 were only temporarily available for analysis and restricted to observation only.

14.2 Miocene

The following species of benthic foraminifera have been arranged in taxonomic order using the suprageneric classifications of Loeblich and Tappan (1987) for calcareous-walled taxa, and Kaminski (2004) for agglutinated. Species identifications have been based in large part on the taxonomic works of Boersma (1984), Kohl (1985), Papp and Schmid (1985), Van Morkhoven et al. (1986), Kaminski and Geroch (1993) and Kaminski and Gradstein (2005). Planktonic foraminifera are arranged in alphabetical order by genus. Species identifications have been based largely on the taxonomic works of Kennett and Srinivasan (1983), Bolli and Saunders (1985) and Spezzaferri (1994).

Family RHABDAMMINIDAE Brady, 1884
Subfamily RHABDAMMININAE Brady, 1884
Genus *Rhabdammina* M. Sars in Carpenter, 1869

Rhabdammina linearis Brady, 1879
Plate 1, fig. 2

Rhabdammina linearis Brady, 1879, p. 37, pl. 3, figs 10-11.

Rhabdammina linearis Brady. – Kaminski & Gradstein, 2005, p. 124, pl. 7, figs 1a-8.

Occurrence: 6 specimens from 3 samples.

Description: Test tubular, with inflated portion forming a bulge midway, medium to large in size, circular in cross section, wall thick, composed of several layers of coarse to very coarse angular sand grains, surface rough, aperture a simple terminal opening.

Remarks: Originally described from the Recent of the South Atlantic, it is a cosmopolitan form that ranges from the Cretaceous to Recent. Specimens

of this species are always broken into small lengths approximately three times as long as wide.

***Rhabdammina* sp. 1**

Plate 1, fig. 3

Occurrence: 162 specimens from 23 samples.

Description: Test tubular, medium to large in size, circular in cross section, invariably flattened, wall medium thickness, composed of several layers of coarse to very coarse angular sand grains, surface rough, aperture a simple terminal opening.

Remarks: We have placed in this category all the described forms, which are invariably broken into small lengths of varying sizes.

***Rhabdammina* spp.**

Occurrence: 368 specimens from 38 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test tubular, wall thick to medium, size small to large, grainsize fine to coarse, occasionally branching.

Remarks: Specimens in this category are always broken and fragmentary.

Subfamily BATHYSIPHONINAE Avnimelech, 1952

Genus *Bathysiphon* Sars, 1872

***Bathysiphon* spp.**

Plate 1, fig. 4

Occurrence: 635 specimens from 37 samples.

Description: Included in this group are all forms displaying the following characteristics: test tubular, wall thick to medium, size small to large, grainsize fine, wall smooth, slight regular constrictions present, non-branching, aperture a simple terminal opening.

Remarks: Specimens in this category are always broken and fragmentary.

Subfamily BATHYSIPHONINAE Avnimelech, 1952

Genus *Nothia* Pflaumann, 1964

Nothia excelsa (Grzybowski, 1898)

Plate 1, fig. 5

Dendrophrya excelsa Grzybowski, 1898, p. 272, pl. 10, figs 2-4.

Nothia excelsa (Grzybowski, 1898). – Geroch & Kaminski, 1992, p. 255, pl. 1, figs 1-4, pl. 2, figs 1-11. – Kaminski & Gradstein, 2005, p. 106, pl. 2A, figs 1-9, pl. 2B, figs 1-11.

Occurrence: 306 specimens from 23 samples.

Description: Test tubular, medium size, rarely branching, usually straight to slightly curved, flattened, wall thin, coarse, moderately rough finish, aperture a simple terminal opening.

Remarks: Originally reported from the Eocene of the Polish Carpathians, this species has been recorded from many Paleogene localities containing tubiditic deep-sea sediments.

Nothia latissima (Grzybowski, 1898)

Plate 1, fig. 6

Dendrophrya latissima Grzybowski, 1898, p. 273, pl. 10, fig. 8.

Nothia latissima (Grzybowski, 1898). – Kaminski & Geroch, 1993, p. 245, pl. 1, figs. 1a-c, 14a,b.

Nothia latissima (Grzybowski). – Kaminski & Gradstein, 2005, p. 113, pl. 3, figs 1-4b.

Occurrence: 28 specimens from 4 samples.

Description: Test tubular, medium size, rarely branching, usually straight to slightly curved,

flattened, wall thin, medium sized grains, finish moderately rough, aperture a simple terminal opening.

Remarks: Originally reported from the Paleogene of the Polish Carpathians, this species has been recorded from many Cretaceous to Paleogene localities containing tubiditic deep-sea sediments.

Nothia robusta (Grzybowski, 1898)

Plate 1, fig. 7

Dendrophrya robusta Grzybowski, 1898, p. 273, pl. 10, fig. 7.

Nothia robusta (Grzybowski, 1898). – Geroch & Kaminski, 1992, pl. 1, figs. 1-4, pl. 2, figs. 1-11.

Nothia robusta (Grzybowski). – Kaminski & Gradstein, 2005, p. 116, pl. 4, figs 1-8.

Occurrence: 24 specimens from 8 samples.

Description: Test very large, robust, tubular, rarely branching, no constrictions or inflations, usually straight to slightly curved, usually flattened with a median furrow, wall thick, medium sized grains, finish usually smooth, wall sometimes contains randomly oriented sponge spicules, aperture a simple terminal opening.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species is very common in deep sea turbiditic sediments, is cosmopolitan in distribution, and has been reported from sediments ranging from the Late Cretaceous to Lower Miocene in age.

***Nothia* spp.**

Occurrence: 504 specimens from 41 samples.

Description: Included in this group are all forms displaying the following characteristics: test tubular, small to large in size, fragmented, with a thin and therefore much flattened wall, grain size fine to coarse, finish usually rough.

Genus *Psammosiphonella* Avnimelich, 1952

Psammosiphonella cylindrica (Glaessner, 1937)

Plate 1, fig. 1

Rhabdammina cylindrica Glaessner, 1937, p. 354, pl. 1, fig. 1.

Rhabdammina cylindrica Glaessner. – Kuhnt & Pletsch, 2001, p. 306, pl. 1, figs 2-3, pl. 2, figs 1-4, pl. 3, figs1-4.

Psammosiphonella cylindrica (Glaessner). – Kaminski & Gradstein, 2005, p. 121, pl. 5, figs 1-13.

Occurrence: 262 specimens from 41 samples.

Description: Test tubular, medium to large in size, circular in cross section, wall thick, composed of several layers of coarse to very coarse angular sand grains, surface rough, aperture a simple terminal opening.

Remarks: Originally described from the Tertiary of the Caucasus, this species occurs with high abundance in the studied samples, but is always broken into small lengths approximately three times as long as wide.

Family RHIZAMMINIDAE Brady, 1879

Genus *Rhizammina* Brady, 1879

***Rhizammina* spp.**

Plate 1, fig. 8

Occurrence: 437 specimens from 38 samples.

Description: Included in this group are all forms displaying the following characteristics: test tubular, small in size, fragmented, with a very thin and delicate wall and irregular outline, grain size medium to coarse, finish usually rough.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus *Saccammina* Carpenter, 1869

Saccammina* cf. *sphaerica Sars, 1872

Plate 1, fig. 9

Saccammina sphaerica Sars, 1872, p. 250.

Saccammina sphaerica Sars. – Brady, 1884, p. 253, pl. 18, figs 11-15. – Charnock & Jones, 1990, pl. 1, fig. 3.

Saccammina cf. *sphaerica* Sars. – Kaminski et al., 2005, p. 392.

Occurrence: 258 specimens from 42 samples.

Description: Test medium size, single chamber, inflated, globular, spherical, wall thin and composed of several layers of quartz grains, test flattened and depressed, grainsize medium, surface texture rough, aperture a small opening on a raised neck.

Remarks: Originally described from the Recent of Norway, this species is a cosmopolitan form that has been reported from the Miocene. Our specimens differ form the original description by having a generally smaller grain size.

***Saccammina* sp. 1**

Plate 1, fig. 10

Occurrence: 52 specimens from 19 samples.

Description: Test medium to large in size, single chamber, inflated, globular, spherical, wall thick and composed of several layers of quartz grains, test flattened and depressed, grainsize medium, surface texture relatively smooth, aperture a small opening on a raised neck.

Remarks: Differs from *S. sphaerica* by having a much thicker wall.

***Saccammina* spp.**

Occurrence: 4 specimens from 2 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test single chambered, sphaerical, small to large in size, fine to medium grained.

Family PSAMMOSPHAERIDAE Haeckel, 1894
Subfamily PSAMMOSPHAERINAE Haeckel, 1894
Genus *Psammosphaera* Schulze, 1875

Psammosphaera* cf. *fusca Schultze, 1875

Plate 1, fig. 12

Psammosphaera fusca Schultze, 1875, p. 113, pl. 2, figs 8a-f.

Occurrence: 149 specimens from 32 samples.

Description: Test small to medium in size, single chamber, inflated, globular, spherical, wall thin, test flattened and depressed, grainsize medium to coarse, surface texture rough, aperture small openings in between sand grains.

***Psammosphaera* sp. 1**

Plate 1, fig. 13

Occurrence: 1 specimen from 1 sample.

Description: Test small to medium in size, single chamber, inflated, globular, spherical, wall thick, composed of several layers of quartz grains, test flattened and depressed, grainsize medium, surface texture smooth, aperture small openings in between sand grains.

Remarks: Differs from *Psammosphaera* sp. 2 in having a much thicker wall.

***Psammosphaera* spp.**

Occurrence: 4 specimens from 3 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test single chambered, small to large, coarse grained.

Family HIPPOCREPINIDAE Rhumbler, 1895
Subfamily HIPPOCREPININAE Rhumbler, 1895
Genus *Jaculella* Brady, 1879

***Jaculella* sp. 1**

Plate 1, fig. 14

Occurrence: 1 specimen from 1 sample.

Description: Test tubular, tapering, conical, wall of medium thickness, comprising several layers of medium sized quartz grains, surface with a rough finish.

Family HYPERAMMINIDAE Eimer & Fickert, 1899
Subfamily HYPERAMMININAE Eimer & Fickert, 1899
Genus *Hyperammina* Brady, 1878

Hyperammina elongata Brady, 1878

Plate 1, fig. 15

Hyperammina elongata Brady, 1878, p. 433, pl. 1, figs 16,18,19.

Hyperammina elongata Brady. – Jones, 1994, p. 33, pl. 23, fig. 8. – Kaminski et al., 2005, p. 386, pl. 1, figs 16,18,19.

Occurrence: 17 specimens from 5 samples.

Description: Test medium to large in size, single inflated proloculus followed by a single tube, somewhat irregular in appearance, wall of medium thickness and composed of several layers of quartz grains, test usually flattened and depressed, grainsize coarse, surface texture rough, aperture a simple opening at the end of the tubular section.

Remarks: Originally described from the Recent of the Arctic Ocean, this species has also been recorded from Miocene sediments of the Greenland Sea.

***Hyperammina* spp.**

Occurrence: 6 specimens from 6 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test elongate, single inflated proloculus followed by a single tube, test usually flattened and depressed, grainsize fine to coarse, aperture a simple opening at the end of the tubular section.

Family AMMODISCIDAE Reuss, 1862
Subfamily AMMODISCINAE Reuss, 1862
Genus *Ammodiscus* Reuss, 1862

Ammodiscus cretaceus (Reuss, 1845)

Plate 1, fig. 16, Plate 2, fig. 5

Operculina cretacea Reuss, 1845, p. 35, pl. 13, figs 64-65.

Ammodiscus cretacea (Reuss). – Cushman, 1934, p. 45.

Ammodiscus cretaceus (Reuss). – Kaminski & Gradstein, 2005, p. 147, pl. 14, figs 1a-10.

Occurrence: 17 specimens from 9 samples.

Description: Test medium to large in size, planispiral, evolute, single chamber increasing in size gradually as grown, eight to eleven coils in the adult form, chamber somewhat inflated, sutures distinct, slightly depressed, surface smooth, with radial growth lines visible, wall thick, aperture a simple terminal opening.

Remarks: Originally described from the Late Cretaceous of the Czech Republic, this species has been reported from Cretaceous to Eocene deep-water turbidite deposits from many localities.

Ammodiscus glabratus Cushman & Jarvis, 1928

Plate 2, fig. 3

Ammodiscus glabratus Cushman & Jarvis, 1928, p. 87, pl. 12, fig. 6.

Ammodiscus glabratus Cushman & Jarvis. – Kaminski & Gradstein, 2005, p. 148, pl. 15, figs 1-6.

Occurrence: 1 specimen from 1 sample.

Description: Test medium to large in size, planispiral, biconcave, evolute, single chamber increasing in size gradually as grown, chamber inflated, increasing in thickness rapidly as grown, sutures slightly depressed, surface smooth, wall thick, aperture a simple terminal opening.

Remarks: Originally described from the Paleogene of Trinidad, this species has been described from many localities ranging from Maastrichtian to Eocene in age.

Ammodiscus latus Grzybowski, 1898

Plate 1, fig. 17

Ammodiscus latus Grzybowski, 1898, p. 282, pl. 10, figs 27-28.

Ammodiscus latus Grzybowski. – Kaminski & Gradstein, 2005, p. 152, pl. 16a, figs 1-8, p. 153, pl. 16b, figs 1-6.

Occurrence: 100 specimens from 26 samples.

Description: Test medium to large in size, planispiral, evolute, single chamber increasing in size gradually as grown, few coils, three to five in adult, chamber much inflated, large, sutures depressed, surface with a rough texture, wall medium thickness, aperture a simple terminal opening.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species has been recorded from the Eocene to Oligocene of the Tethys, and up to the Middle Miocene of the Arctic.

Ammodiscus* aff. *peruvianus Berry, 1928

Plate 2, figs 1,2

Ammodiscus peruvianus Berry, 1928, p. 342, fig. 27.

Ammodiscus peruvianus Berry. – Kender et al., 2005, p. 261, pl. 10, fig. I. – Kaminski & Gradstein, 2005, p. 157, pl. 18, figs 1-6.

Occurrence: 8 specimens from 4 samples.

Description: Test of medium size, planispiral, evolute, elongated along the long axis, biconcave, single chamber increasing in size gradually as grown, few coils, chamber much inflated, large, sutures depressed, surface with a smooth texture, wall medium thickness, aperture a simple terminal opening.

Remarks: Originally described from the Eocene of Peru, this is a cosmopolitan species recorded from many localities of Cretaceous to Eocene age. Our specimens differ from the original description in having a slightly larger and more inflated chamber.

***Ammodiscus* sp. 3**

Occurrence: 2 specimens from 1 sample.

Description: Test small in size, planispiral, evolute, single chamber increasing in size gradually as grown, chamber thin, sutures slightly depressed, surface with a rough texture, wall thin, aperture a simple terminal opening.

Remarks: This species is characterized by its very small size and thin wall.

***Ammodiscus* spp.**

Occurrence: 6 specimens from 5 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test planispiral, generally round in outline, evolute, one chamber increasing in size as grown, aperture a terminal opening.

Subfamily TOLYPAMMININAE Cushman, 1928

Genus *Ammolagena* Eimer & Fickert, 1899

Ammolagena clavata (Jones & Parker, 1860)

Plate 2, figs 4-6, Plate 12, fig. 9

Trochammina irregularis (d'Orbigny) var. *clavata* Jones & Parker, 1860, p. 304.

Ammolagena clavata (Jones & Parker). – Kaminski & Gradstein, 2005, p. 165, pl. 21, figs 1-6.

Occurrence: 24 specimens from 12 samples.

Description: Test attached, medium to large in size, initial proloculus ovoid, followed by an undivided elongate irregular meandering tube-like chamber, inflated, not increasing in size, wall smooth, thin so that it is usually depressed, growth lines can sometimes be seenm, two apertures, one at the terminus of the initial proloculus as a simple opening surrounded by a lip, one at the termination of the tube extension, simple opening.

Remarks: Originally recorded from the Recent of the Mediterranean, this species has a long range from the Early Cretaceous and is common in deep sea environments from both the Pacific and the Atlantic.

Genus *Tolypammina* Rhumbler, 1895

***Tolypammina* spp.**

Plate 2, figs 7,8

Occurrence: 241 specimens from 32 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test unilocular, undivided elongate tube, small, very irregular meandering, wall thin, fine grained, aperture a simple terminal opening.

Subfamily USBEKISTANIINAE Vyalov, 1977

Genus *Glomospira* Rzehak, 1885

Glomospira charoides (Jones & Parker, 1860)

Plate 2, fig. 9

Trochammina squamata Jones & Parker var. *charoides* Jones & Parker, 1860, p. 304.

Glomospira charoides (Jones & Parker). – Berggren & Kaminski, 1990, pl. 1, fig. 2. – Kaminski & Gradstein, 2005, p. 173, pl. 22, figs 1-16.

Occurrence: 244 specimens from 50 samples.

Description: Test rounded in outline, initial proloculus followed by a single undivided chamber, trochospirally enrolled about the axis, about three layers of enrolment, last whorl occasionally deviates from the general coiling, wall smooth, aperture simple opening at the terminus of the tube.

Remarks: This species is a cosmopolitan form described from many localities of Jurassic to Recent age.

Glomospira glomerata (Grzybowski, 1898)

Plate 2, fig. 10

Ammodiscus glomeratus Grzybowski, 1898, p. 285, pl. 11, fig. 4.

"Glomospira" glomerata (Grzybowski). – Kaminski & Gradstein, 2005, p. 179, pl. 24, figs 1-6.

Occurrence: 24 specimens from 7 samples.

Description: Test irregular in shape, comprised of a single undivided chamber, coiled in a repeated open S-shape, or irregularly, not enrolled, wall coarse, thick, surface with a rough finish, aperture a terminal opening.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species is a cosmopolitan deep-water form recorded from Late Cretaceous to Oligocene sediments.

Glomospira gordialis (Jones & Parker, 1860)

Plate 2, fig. 11

Trochammina squamata Jones & Parker var. *gordialis* Jones & Parker, 1860, p. 304.

Glomospira gordialis (Jones & Parker). – Berggren & Kaminski, 1990, pl. 1, fig. 1.

– Kaminski & Gradstein, 2005, p. 184, pl. 25, figs 1-8.

Occurrence: 512 specimens from 53 samples.

Description: Test rounded in outline, compressed, with initial hidden small proloculus followed by a single undivided chamber trochospirally enrolled for one layer, then glomospirally coiled along a general plane, last whorl occasionally deviates from the general coiling, wall smooth, aperture simple opening at the terminus of the tube.

Remarks: Originally described from the Recent of the Indian Ocean and Arctic Sea, this species is a cosmopolitan deep-water form recorded from Late Cretaceous to Recent sediments.

Glomospira irregularis (Grzybowski, 1898)

Plate 2, fig. 12

Ammodiscus irregularis Grzybowski, 1898, p. 285, pl. 11, figs 2, 3.

Glomospira irregularis (Grzybowski). – Kaminski & Geroch, 1993, p. 256, pl. 6, fig. 6-8b. – Kaminski & Gradstein, 2005, p. 187, pl. 26, figs 1a-7.

Occurrence: 184 specimens from 41 samples.

Description: Test irregular in outline, consisting a single undivided chamber, streptospirally enrolled, somewhat irregular in appearance, wall rough, aperture simple opening at the terminus of the tube.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species is a cosmopolitan deep-water form recorded from Jurassic to Recent sediments.

Glomospira* aff. *serpens (Grzybowski, 1898)

Plate 2, fig. 13

Ammodiscus serpens Grzybowski, 1898, p. 285, pl. 10, fig. 31.

Glomospira serpens (Grzybowski). – Kaminski & Gradstein, 2005, p. 187, pl. 26, figs 1a-7.

Occurrence: 2 specimens from 2 samples.

Description: Test flattened ovate in outline, consisting a single undivided chamber elliptically enrolled, milioline-like, arranged around a central axis at 60 degree angles to the preceeding whorls, chamber inflated, wall smooth, of medium thickness, aperture simple opening at the terminus of the tube.

Remarks: Differs from the original description by having wider chamber with thinner wall. *G. serpens* was originally described from the Eocene of the Polish Carpathians. This species is a cosmopolitan deep-water form recorded from Cretaceous to Eocene sediments.

***Glomospira* sp. 1**

Plate 2, fig. 14

Glomospirella sp. Schröder et al., 1988, p. 32, pl. 4, fig. 15.

Glomospira charoides ssp. 1 Bender, 1995, p. 45, pl. 3, fig. 3.

Occurrence: 22 specimens from 11 samples.

Description: Test rounded in outline, compressed, with initial hidden small proloculus followed by a single undivided chamber trochospirally enrolled for only the first whorl, then glomospirally coiled along a general plane almost planispiral, last whorl deviates slightly from the general coiling, chamber thin, wall smooth, aperture simple opening at the terminus of the tube.

Remarks: Differs from *G. gordialis* in having a much smaller initial trochospiral part. Described from offshore Ivory Coast and Ghana, and the south Pacific.

***Glomospira* sp. 2**

Plate 2, fig. 15

Occurrence: 2 specimens from 2 samples.

Description: Test large, rounded in outline, compressed, with initial proloculus followed by a single undivided chamber trochospirally enrolled for only the first whorl, then glomospirally coiled along a general plane almost planispiral, chamber thick, wall rough, grainsize coarse, aperture simple opening at the terminus of the tube.

Remarks: Differs from Glomospira sp. 1 in having a much coarser wall and thicker chamber.

***Glomospira* spp.**

Occurrence: 5 specimens from 4 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test single undivided chamber, not increasing rapidly in size, coiled trochospiral or irregular.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Hormosinella* Shchedrina, 1969

Hormosinella carpenteri (Brady, 1884)

Plate 2, fig. 16

Trochammina (Hormosina) carpenteri Brady, 1881, p. 51 [no figure given].

Hormosina carpenteri Brady, 1884, pl. 31, figs 16-22 [earliest figure].

Hormosinella carpenteri (Brady). – Jones, 1994, p. 44, pl. 39, figs 14-18.

Occurrence: 1 specimen from 1 sample.

Description: Test large, uniserial, elongate chambers, tapering towards the terminal end, wall coarse, with a rough texture, aperture a terminal simple opening.

Remarks: Originally described from the Recent of the Atlantic.

Genus *Reophanus* Saidova, 1970

Reophanus berggreni Gradstein & Kaminski, 1997

Plate 3, figs 1,2

Reophanus berggreni Gradstein & Kaminski, 1997, p. 220, textfig. 4, fig. 5, 1-7b.

Reophanus berggreni Gradstein & Kaminski. – Kaminski & Gradstein, 2005, p. 265, pl. 50, figs 1-7.

Occurrence: 4 specimens from 3 samples.

Description: Test very large, uniserial, chambers rounded to oval in outline, wall coarse, with a rough texture, aperture a terminal simple opening.

Remarks: Originally described from the Oligocene of the North Sea, this species occurs only as large fragments. Also described from the Miocene of the Fram Strait, Greenland Sea. Our specimens differ from the original in having a coarser grainsize.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Subreophax* Saidova, 1975

Subreophax scalaris (Grzybowski, 1896)

Plate 3, figs 3,4

Reophax guttifera Brady var. *scalaria* Grzybowski, 1896, p. 277, pl. 8, fig. 26.

Subreophax scalaris (Grzybowski). – Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 2, figs 16-17.

Reophax scalaris (Grzybowski). – Kaminski & Gradstein, 2005, p. 279, pl. 55, figs 1-7.

Occurrence: 110 specimens from 35 samples.

Description: Test small, uniserial, elongate rectilinear or sinuous, chambers increasing in size only slowly, rounded globular, collapsed, sutures depressed, wall thin, rough texture, aperture a simple terminal opening.

Remarks: Originally described from the Late Cretaceous of the Polish Carpathians, this species has also been recorded from many Cretaceous to Oligocene localities including Trinidad and the Labrador Sea.

***Subreophax* sp. 1**

Plate 3, fig. 6

Occurrence: 1 specimen from 1 sample.

Description: Test uniserial, elongate rectilinear, chambers increasing in size only slowly, slightly globular, sutures slightly depressed, chamebrs collepsed, wall thin, rough taxture, aperture a simple terminal opening.

Family ASCHEMOCELLIDAE Vyalov, 1966

Genus *Aschemocella* Vyalov, 1966

Aschemocella grandis (Grzybowski, 1898)

Plate 3, fig. 5

Reophax grandis Grzybowski, 1898, p. 277, pl. 10, figs 13-15.

Aschemocella grandis (Grzybowski). – Kaminski & Geroch, 1993, p. 249, pl. 2, figs 8-10.

Aschemocella grandis (Grzybowski). – Kaminski & Gradstein, 2005, p. 229, pl. 39, figs 1-8b.

Occurrence: 60 specimens from 16 samples.

Description: Test large, uniserial, chambers not increasing in size as added, rounded globular, collapsed, sutures much depressed, wall thin, rough texture, aperture a small simple terminal opening on a slight neck.

Remarks: Usually recovered as single chambers, this species has a propensity to break along the sutures. It was originally described from the Paleocene of the Polish Carpathians, as is known also from Trinidad, the North Sea, Labrador Sea and Morocco. Ranges from the Campanian to Lower Miocene.

Genus *Kalamopsis* de Folin, 1883

***Kalamopsis* spp.**

Plate 3, fig. 7

Occurrence: 4 specimens from 2 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test elongate rectilinear, of medium size, chambers tubular, sutures slightly depressed, wall thick, surface usually smooth.

Family REOPHACIDAE Cushman, 1927
Genus *Hormosinelloides* Saidova, 1975

Hormosinelloides guttifer (Brady, 1884)
Plate 3, fig. 8

Reophax guttifer Brady, 1881, p. 49 [no figure given].

Reophax guttifer Brady, 1884, pl. 31, figs 10-15 [earliest figure].

Hormosinelloides guttifer (Brady). – Zheng & Fu, 2001.

Occurrence: 1 specimen from 1 sample.

Description: Test medium size, uniserial, chambers pyriform, collapsed, attached by a short stolon, sutures depressed, wall thin, rough texture, aperture a small simple terminal opening on a slight neck.

Remarks: Originally described from the Recent of the South Atlantic, this is a cosmopolitan species recorded from Late Cretaceous to Recent deep-sea sediments.

Genus *Reophax* de Montfort, 1808

Reophax pilulifer (Brady, 1884)
Plate 3, fig. 9

Reophax pilulifer Brady, 1884, p. 292, pl. 30, figs 18-20.

Reophax pilulifer Brady. – Kaminski & Gradstein, 2005, p. 273, pl. 53, figs 1a-9.

Occurrence: 10 specimens from 6 samples.

Description: Test medium to large in size, uniserial, straight to arcuate, up to five chambers in adult, chambers rounded globular, increasing in size rapidly as added, collapsed, sutures depressed, wall coarse grained, single-layered, rough texture, aperture a small simple terminal opening on a slight shoulder.

Remarks: Originally described from the Recent of the North Atlantic, this is a long ranging cosmopolitan species recorded from all the major oceans.

***Reophax* spp.**

Occurrence: 2 specimens from 1 sample.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test uniserial, elongate, multilocular.

Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894
Genus *Hormosina* Brady, 1879

Hormosina glabra Cushman & Stainforth, 1945
Plate 3, fig. 10

Hormosina glabra Cushman & Stainforth, 1945, p. 14, pl. 1, fig. 9.

Occurrence: 20 specimens from 12 samples.

Description: Test medium to large in size, uniserial, rectilinear, chambers numerous, pyriform globular, increasing in size gradually as added, collapsed, sutures slightly depressed, wall thick, fine grained, smooth texture, aperture a small simple terminal opening on a slight shoulder.

Remarks: Originally described from the Middle Miocene of Trinidad.

Hormosina globulifera Brady, 1879
Plate 3, fig. 11

Hormosina globulifera Brady, 1879, p. 60, pl. 4, figs 4-5.

Hormosina globulifera Brady. – Charnock & Jones, 1990, p. 162, pl. 4, figs 2,3, pl. 15, fig. 3. – Jones, 1994, p. 44, pl. 39, figs 1-4, 6.

Occurrence: 36 specimens from 28 samples.

Description: Test medium to large in size, uniserial, straight to arcuate, up to five chambers in adult, chambers rounded globular, increasing in size sometimes rapidly, collapsed, sutures depressed, wall thick, multi-layered, medium grained, smooth texture, aperture a small simple terminal opening on a raised shoulder.

Remarks: Differs from *Reophax pilulifer* in having a multi-layered wall and finer grains. Originally described from the Recent of the North Atlantic, has also been recorded from the Paleogene of the North Sea.

Genus *Pseudonodosinella* Saidova, 1970

Pseudonodosinella nodulosa (Brady, 1879)

Plate 3, fig. 12

Reophax nodulosa Brady, 1879, p. 52, pl. 4, figs 7,8.

Pseudonodosinella nodulosa (Brady). – Loeblich & Tappan, 1987, p. 61, pl. 46, figs 5,6. – Kaminski & Gradstein, 2005, p. 259, pl. 49, figs 1-9.

Occurrence: 1 specimen from 1 sample.

Description: Test uniserial, elongate rectilinear, chambers increasing in size only slowly, strongly embracing, subglobular, sutures depressed, wall thick, smooth texture, aperture a simple terminal opening.

Remarks: Originally described from the Recent of the South Atlantic, this species has been been recorded from Eocene to Recent sediments.

Family LITUOTUBIDAE Loeblich & Tappan, 1984

Genus *Lituotuba* Rhumbler, 1895

Lituotuba lituiformis (Brady, 1879)

Plate 3, figs 13-15

Trochammina lituiformis Brady, 1879, p. 59, pl. 5, fig. 16.

Lituotuba lituiformis (Brady). – Kaminski & Gradstein, 2005, p. 287, pl. 58, figs 1-8.

Occurrence: 8 specimens from 5 samples.

Description: Test medium to large in size, sometimes uncoiling irregular straptospiral, chambers elongate of varying length, subglobular, sutures depressed, wall thin, smooth texture, aperture a simple terminal opening.

Remarks: Originally described from the Recent of the West Indies, this species has been been recorded from Cretaceous to Recent sediments from localities including the Pacific and South China Sea.

Genus *Paratrochamminoides* Soliman, 1972

Paratrochamminoides challengeri (Rögl, 1995)

Plate 3, fig. 16

Trochammina proteus (Karrer). – Brady, 1884, p. 341, pl. 40, figs 1,2 (not 3). – Cushman, 1910, p. 98, figs 142-144.

Trochamminoides challengeri Rögl, 1995, p. 256.

Paratrochamminoides challengeri (Rögl). – Kaminski & Kuhnt, 2004, p. 280.

Occurrence: 7 specimens from 6 samples.

Description: Test medium to large in size, initially irregular streptospiral, becoming planispiral, chambers elongate of fixed length, globular, sutures depressed, wall thin, smooth texture, aperture a simple terminal opening.

Remarks: Originally described from the Recent of the West Atlantic, this species was re-described by Rögl from Brady's original figures. It has also been recorded from the Recent of the Pacific.

Paratrochamminoides deflexiformis (Noth, 1912)

Plate 3, fig. 17

Trochammina deflexiformis Noth, 1912, p. 26, figs 10a-b.

Paratrochamminoides deflexiformis (Noth). – Kender, Kaminski & Cieszkowski, 2005, p. 263, fig. 11, K1,2. – Kaminski & Gradstein, 2005, p. 293, pl. 60, figs 1-4

Occurrence: 12 specimens from 8 samples.

Description: Test medium to large in size, oval in outline, irregular streptospiral, chambers numerous, eight to ten in the final whorl, bead-like, globular, sutures depressed, wall thin, smooth texture, aperture a simple terminal opening.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species has also been recorded from the Paleogene of Morocco and Trinidad, and the Maastrichtian of the Polish Carpathians.

Paratrochamminoides gorayskiformis Kender, Kaminski & Jones 2006

Plate 3, fig. 18

Paratrochamminoides gorayskiformis Kender, Kaminski & Jones, 2006, p. 467, pl. 1, figs 7-10.

Occurrence: 3 specimens from 3 samples.

Description: Test oval in outline, coiling triloculine, coiled in three planes about the long axis, chambers of varying length, from elongate to distinctly bead-like, approximately five in the last whorl, wall finely agglutinated, finish smooth, wall thin, aperture at the open end of the tube.

Remarks: Originally described from the Oligocene section of the well studied in this paper.

Paratrochamminoides heteromorphus (Grzybowski, 1898)

Plate 4, fig. 1

Trochammina heteromorpha Grzybowski, 1898, p. 286, pl. 11, fig. 16.

Paratrochamminoides heteromorphus (Grzybowski). – Kaminski & Geroch, 1993, p. 258, pl. 7, figs 3-5. – Kaminski & Gradstein, 2005, p. 298, pl. 301, figs 1-10.

Occurrence: 2 specimens from 2 samples.

Description: Test large, coiling glomospiral to trochospiral, in two planes, uncoiling in later stage, chambers subglobular, bead-like, inflated, approximately six in the last whorl, wall finely agglutinated, finish relatively smooth, wall thin, aperture a simple terminal opening.

Remarks: Originally described from the Eocene of the Polish Carpathians, this species has been recorded from the Maastrichtian and Paleogene of Trinidad and Morocco.

Paratrochamminoides mitratus (Grzybowski, 1901)

Plate 4, fig. 2

Trochammina mitrata Grzybowski, 1901, p. 280, pl. 8, fig. 3.

Paratrochamminoides mitratus (Grzybowski). – Kaminski & Geroch, 1993, p. 278, pl. 16, figs 4,6. – Kaminski & Gradstein, 2005, p. 302, pl. 304, figs 1-7.

Occurrence: 1 specimen from 1 sample.

Description: Test large, coiling streptospiral to triloculine, changing direction abruptly between whorls, compact, chambers globular, bead-like, inflated, approximately six in the last whorl, wall finely agglutinated, finish relatively smooth, wall thin, aperture a simple terminal opening.

Remarks: Originally described from the Paleogene of the Polish Carpathians, this species has also been recorded from the North Sea, Trinidad and Morocco,

Paratrochamminoides olszewskii (Grzybowski, 1898)

Plate 4, fig. 3

Trochammina olszewskii Grzybowski, 1898, p. 298, pl. 11, fig. 6.

Paratrochamminoides olszewskii (Grzybowski). – Kaminski & Geroch, 1993, p. 257, pl. 7, figs 1a-2b.

Paratrochamminoides olszewskii (Grzybowski). – Kaminski & Gradstein, 2005, p. 307, pl. 64, figs 1a-7.

Occurrence: 4 specimens from 3 samples.

Description: Test small, oval in outline, coiling glomospiral, chambers globular, elongate of varying length, three to five in the last whorl, wall finely agglutinated, finish smooth, wall thin, aperture a simple terminal opening.

Remarks: Originally described from the Paleogene of the Polish Carpathians, this species is cosmopolitan and known from Cretaceous to Eocene sediments.

***Paratrochamminoides* sp. 1**

Plate 4, figs 4-9, Plate 5, figs 1,2

Occurrence: 11 specimens from 6 samples.

Description: Test large, oval to round in outline, coiling streptospiral, umbilicus open, chambers globular, large and rectangular in shape, usually slightly longer than wide, sometimes square, about four in the last whorl, sutures distinct, depressed, wall finely agglutinated, finish medium coarse or smooth, wall thin, aperture a simple terminal opening, specimens invariably collapsed and compressed in any plane.

Remarks: A similar but much smaller form was described as *Trochamminoides pseudointermedius* Săndulescu (1972) from the Late Cretaceous of the Eastern Carpathians, Romania. As the morphology of this form is rather non-descript, the size small (and therefore may be a juvenile of another species), the age Cretaceous (and we observe none of these species in the Oligocene section of the well), we regard the specimens in this report most likely to be of another species.

***Paratrochamminoides* spp.**

Occurrence: 35 specimens from 18 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test streptospirally enrolled, numerous ovate to globular chambers, wall thin.

Genus *Conglophragmium* Bermúdez & Rivero, 1963

Conglophragmium irregulare (White, 1928)

Plate 5, fig. 3

Trochamminoides irregularis White, 1928, p. 307, pl. 42, fig. 1.

Conglophragmium irregularis (White). – Kaminski & Gradstein, 2005, p. 286, pl. 57, figs 1-6.

Occurrence: 15 specimens from 11 samples.

Description: Test streptospiral, chambers few in number, globular, large, spherical, wall finely agglutinated, finish smooth, wall thin, aperture a long interiomarginal arch.

Remarks: Originally described from the Paleocene of Mexico, this species is cosmopolitan and known from Late Cretaceous to Oligocene sediments.

Family TROCHAMMINOIDAE Haynes & Nwabufo-Ene, 1998

Genus *Trochamminoides* Cushman, 1910

Trochamminoides folius (Grzybowski, 1898)

Plate 5, fig. 4

Trochammina folium Grzybowski, 1898, p. 288, pl. 11, figs 7-9.

Trochamminoides folius (Grzybowski). – Kaminski & Geroch, 1993, p. 306, pl. 9, figs 1a-4b.

Occurrence: 2 specimens from 2 samples.

Description: Test oval in outline, coiling irregular becoming planispiral, uncoiling, chambers globular, elongate tube-like, wall finely agglutinated, finish smooth, wall thick, aperture a simple terminal opening.

Remarks: Originally described from the Paleogene of the Polish Carpathians.

Trochamminoides subcoronatus (Grzybowski, 1896)

Plate 5, figs 5,6

Trochammina subcoronata Grzybowski, 1896, p. 283 - 284, pl. 9, fig. 3a-c.

Trochamminoides subcoronatus (Grzybowski). – Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 192, pl. 4, fig. 19.

Trochamminoides subcoronatus (Grzybowski). – Kaminski & Gradstein, 2005, p. 319, pl. 67, figs 1a-6.

Occurrence: 18 specimens from 10 samples.

Description: Test planispiral, chambers globular, spherical, about six in the final whorl, wall finely agglutinated, finish smooth, wall thin, aperture a simple terminal opening.

Remarks: Originally described from the Paleocene of the Polish Carpathians, this species is cosmopolitan and known from Late Cretaceous to Eocene sediments.

***Trochamminoides* spp.**

Occurrence: 3 specimens from 3 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test irregularly coiled becoming planispiral, numerous ovate to globular chambers, wall thin.

Family HAPLOPHRAGMOIDIDAE Maync, 1952

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides* cf. *bradyi (Robertson, 1891)

Plate 5, fig. 7

Trochammina bradyi Robertson, 1891, p. 388.

Haplophragmoides bradyi (Robertson). – Parker, 1954, pl. 1, fig. 16. – Schröder, 1986, p. 637, pl. 3, fig. 4.

Haplophragmoides cf. *bradyi* (Robertson). – Green et al., 2004, p. 124, pl. 1, figs 5-7. – Kaminski et al., 2005, p. 384.

Occurrence: 57 specimens from 16 samples.

Description: Test small, involute planispiral, round in outline, periphery rounded, chambers slightly inflated, four and a half in the final whorl, sutures depressed, straight, radial, wall finely agglutinated, finish smooth, wall thin, aperture a slit at the base of the apertural face.

Remarks: Originally described as *Trochammina robertsoni* by Brady (1887) from the Recent of the British Isles, our specimens have less variability in chamber number and more closely resemble those reported from the Miocene of the Gulf of Mexico and the Fram Strait.

Haplophragmoides horridus (Grzybowski, 1901)

Plate 5, fig. 8

Haplophragmium horridum Grzybowski, 1901, p. 270, pl. 7, fig. 12.

Haplophragmoides horridus (Grzybowski). – Kaminski & Geroch, 1993, p. 318, pl. 15, figs 6-8.

Haplophragmoides horridus (Grzybowski). – Kaminski & Gradstein, 2005, p. 349, pl. 77, figs 1a-6.

Occurrence: 36 specimens from 13 samples.

Description: Test large, involute planispiral, round in outline, periphery rounded, chambers inflated, four and a half in the final whorl, last chamber greatly enlarged, sutures depressed, straight, radial, wall finely agglutinated, finish rough, wall thin, aperture a slit at the base of the apertural face.

Remarks: Originally described from the Paleogene of the Polish Carpathians.

Haplophragmoides nauticus Kender, Kaminski & Jones 2006

Plate 5, figs 10-12

Haplophragmoides nauticus Kender, Kaminski & Jones, 2006, p. 469, pl. 2, figs 1-3.

Occurrence: 23 specimens from 8 samples.

Description: Test planispiral, circular in outline, acute periphery, coiling evolute, nine chambers in the final whorl, chambers truncated triangular (trapezoidal) in shape, increasing in size rapidly as added, sutures straight to sigmoidal, slightly depressed, wall simple, thin, finely agglutinated, smooth finish, aperture slit-like, located at the base of the final chamber.

Remarks: Originally described from the Oligocene section of the well studied in this paper.

Haplophragmoides carinatus Cushman & Renz, 1941

Plate 5, fig. 9

Haplophragmoides carinatus Cushman & Renz, 1941, p. 2, pl. 1, fig. 1.

Occurrence: 25 specimens from 17 samples.

Description: Test involute planispiral, round in outline, periphery acute, carinate, umbilicus slightly depressed, chambers increasing in size gradually as added, about ten in the final whorl, sutures slightly depressed, straight, radial, wall finely agglutinated, finish smooth, wall thin, aperture a slit at the base of the apertural face.

Remarks: Originally described from the Paleogene of the Polish Carpathians, is a true cosmopolitan species recorded from the Late Cretaceous to Middle Miocene.

***Haplophragmoides* sp. 1**

Plate 6, fig. 1

Occurrence: 4 specimens from 2 samples.

Description: Test large, involute planispiral, round in outline, periphery rounded, umbilicus depressed, chambers distinctly globular, five in the final whorl, sutures depressed, straight, radial, wall coarsely agglutinated, finish rough, wall thick, aperture a slit at the base of the apertural face.

***Haplophragmoides* spp.**

Plate 6, fig. 2

Occurrence: 35 specimens from 21 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test planispiral, wall agglutinated, chambers increasing in size as added.

Family DICAMMINIDAE Loeblich & Tappan, 1984

Genus *Glaphyrammina* Cushman, 1910

Glaphyrammina americana (Cushman, 1910)

Plate 6, figs 3,4

Ammobaculites americanus Cushman, 1910, p. 117, figs 1-4.

Glaphyrammina americana (Cushman). – Loeblich & Tappan, 1987, p. 68, pl. 51, figs 7-10. – Jones, 1994, p. 40, pl. 34, figs 1-4.

Occurrence: 1 specimen from 1 sample.

Description: Test evolute planispiral, becoming uncoiled, oval in outline, periphery rounded, umbilicus depressed, chambers increasing in size rapidly as added, becoming elongate, seven to ten in the final whorl, sutures depressed, straight, slightly oblique, wall coarsely agglutinated, with a rough finish, wall thin.

Remarks: Originally described from the Recent of the North Pacific, this species has also been recorded by Brady (1884) from the Recent of the South Atlantic.

Family SPHAERAMMINIDAE Cushman, 1933

Subfamily PRAESPHAERAMMININAE Kaminski & Mikhalevich 2004

Genus *Praesphaerammina* Kaminski & Filipescu 2000

***Praesphaerammina* sp. 1**

Plate 6, fig. 5

Occurrence: 1 specimen from 1 sample.

Description: Test very large in size, planispiral, three to four strongly overlapping chambers, final chamber is so large it makes up the majority of test, wall very thick, coarse, with a rough texture.

***Praesphaerammina* spp.**

Occurrence: 5 specimens from 2 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test large, planispirally enrolled, involute, with about four strongly overlapping chambers per whorl, final chamber embracing and overlapping more than half of test, wall fine, with a rough to smooth finish.

Remarks: Usually occurs as fragments of very large specimens.

Family LITUOLIDAE de Blainville, 1827

Genus *Discamminoides* Bronnimann, 1951

***Discamminoides* sp. 1**

Plate 6, fig. 6

Occurrence: 1 specimen from 1 sample.

Description: Test large, involute, planispiral becoming uniserial, flattened, four to five chambers in last coil, up to five chambers in uniserial part, increasing in size steadily, as added, initial coiled part either large or small depending on micro- or megalo- spheric generation, periphery acute, sutures straight, seen as slight depression or undulation of test surface, or only visible as internal layer, aperture a terminal slit, wall bilamellar, internal layer thicker at peripheral part, coarse and sometimes speculated, with thin tubular alveoles, outer layer medium to coarse grained and thin.

Remarks: This species occurs in high abundance in the Oligocene section of the well.

Family AMMOSPHAEROIDINIDAE Cushman, 1927

Subfamily AMMOSPHAEROIDININAE Cushman, 1927

Genus *Ammosphaeroidina* Cushman, 1910

Ammosphaeroidina pseudopauciloculata (Mjatliuk, 1966)

Plate 6, fig. 7

Cystamminella pseudopauciloculata Mjatliuk, 1966, p. 246, pl. 1, figs 5-7, pl. 2, fig. 6, pl. 3, fig. 3.

Ammosphaeroidina pseudopauciloculata (Mjatliuk). – Mjatliuk, 1970, p. 104, pl. 15, fig. 6, pl. 30, figs 10-14. – Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 193, pl. 8, figs 3-5. – Green et al., 2004, p. 125, pl. 5, fig. 3.

Occurrence: 42 specimens from 14 samples.

Description: Test streptospirally enrolled, rounded in outline, chambers globular, increasing rapidly in size as added, embracing so that only four are visible in the final whorl, sutures depressed, straight, wall fine grained, surface smoothly finished, aperture a low interiomarginal arch.

Remarks: Also described from the Paleogene of Trinidad and Miocene of the Gulf of Mexico.

***Ammosphaeroidina* spp.**

Plate 8, fig. 2

Occurrence: 30 specimens from 7 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test streptospirally enrolled, rounded in outline, chambers globular, increasing rapidly in size as added, embracing, sutures depressed, straight, wall fine grained.

Subfamily RECURVOIDINAE Alekseychik-Mitskevich1973

Genus *Budashevaella* Loeblich & Tappen, 1964

Budashevaella multicamerata (Voloshinova & Budasheva, 1961)

Plate 6, fig. 8

Circus multicamerata Voloshinova, 1961, p. 201, pl. 7, figs 6a-c, pl. 8, 1a-c.

Budashevaella multicamerata Voloshinova. – Kaminski & Gradstein, 2005, p. 388, pl. 90, figs 1a-6b.

Occurrence: 7 specimens from 7 samples.

Description: Test medium to large in size, evolute, becoming planispiral, round in outline, periphery subrounded, umbilicus depressed, chambers numerous, about ten in the final whorl, increasing in size as added, sutures depressed, straight, wall coarsely agglutinated, with a rough finish, wall thick, aperture an indistinct slit at the base of the apertural face.

Remarks: Originally described from the Oligocene - Miocene of the Kamchatka Peninsula, this species is cosmopolitan and has been recorded from the Pacific and Atlantic Oceans.

Genus *Cribrostomoides* Cushman, 1910

Cribrostomoides subglobosus (Cushman, 1910)

Plate 6, fig. 9

Lituola subglobosa Cushman, 1910, p. 253.

Cribrostomoides subglobosus (Cushman). – Jones, Bender, Charnock, Kaminski & Whittaker, 1993, pl. 1, figs 1-5.

Cribrostomoides subglobosus subglobosus (Cushman). – Kaminski & Gradstein, 2005, p. 391, pl. 92, figs 1-3.

Occurrence: 19 specimens from 13 samples.

Description: Test medium to large in size, involute, trochospiral becoming planispiral, round in outline, periphery rounded, umbilicus depressed, chambers inflated, about six in the final whorl,

increasing in size rapidly as added, sutures slightly depressed or flush with surface, straight, wall coarsely agglutinated, with a rough finish, wall thick, aperture a slit at the base of the apertural face, slightly raised to an areal position, bordered by a distinct lip.

Remarks: Originally described from the Recent of the North Pacific, this species has also been recorded by Brady (1884) from the Recent of the all the major oceans. It has also been recorded from many localities from the Cretaceous to Recent.

Cribrostomoides sp. 1

Plate 6, fig. 10

Occurrence: 4 specimens from 4 samples.

Description: Test very large in size, involute, nearly planispiral, round in outline, periphery rounded, umbilicus depressed, chambers inflated, about five in the final whorl, increasing in size rapidly as added, sutures slightly depressed or flush with surface, straight, wall coarsely agglutinated, with a rough finish, wall thick, aperture indistinct.

Remarks: This species differs from *C. subglobosus* in having a much larger test and more depressed sutures.

***Cribrostomoides* spp.**

Occurrence: 30 specimens from 7 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test involute, nearly planispiral, round in outline, periphery rounded, umbilicus depressed, chambers inflated, increasing in size rapidly as added, sutures slightly depressed or flush with surface, straight, wall coarsely agglutinated, with a rough finish, wall thick, aperture indistinct.

Genus *Recurvoides* Earland, 1934

Recurvoides azuaensis Bermúdez, 1949

Plate 7, figs 1,4

Recurvoides azuaensis Bermúdez, 1949, pl. 1, figs 35-37.

Recurvoides azuaensis Bermúdez. – Green, 2004, p. 126, pl. 3, fig. 6.

Occurrence: 39 specimens from 17 samples.

Description: Test medium to large in size, streptospiral, involute, tightly coiled, round to oval in outline, periphery rounded, chambers increasing in size rapidly as added, about five in the final whorl, sutures slightly depressed or flush with surface, straight, wall coarsely agglutinated, with a rough finish, wall relatively thin so that specimens are flattened, aperture a narrow areal slit near the base of the final chamber.

Remarks: Originally described from the Oligocene of the Dominican Republic, this species has also been recorded from the Miocene of the Gulf of Mexico.

***Recurvoides* sp. 1**

Plate 7, figs 2,3

Occurrence: 39 specimens from 17 samples.

Description: Test small, consisting of five to seven elongated chambers tightly enrolled to form spherical test, coiling streptospiral becoming just off planispiral, sutures slightly depressed, wall coarse, with a rough finish, aperture an areal slit.

***Recurvoides* spp.**

Occurrence: 32 specimens from 19 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test subglobular, streptospirally enrolled, generally few chambers

per whorl, generally trochospiral to planispiral or may show an abrupt change in plane of coiling, wall coarsely agglutinated, medium to thick, surface usually roughly finished, aperture areal.

Family AMMOBACULINIDAE Saidova, 1981
Subfamily AMMOBACULININAE Saidova, 1981
Genus *Bulbobaculites* Maync, 1952

***Bulbobaculites* sp. 1**

Plate 7, fig. 5

Occurrence: 1 specimen from 1 sample.

Description: Test of medium size, elongate, early stage with streptospirally enrolled globular and inflated chambers, later chambers uncoiled and rectilinear, sutures distinct, depressed and horizontal, wall coarsely finished and simple, aperture terminal, a single small rounded opening.

Family SPIROPLECTAMMINIDAE Cushman, 1927
Subfamily VULVULININAE Saidova, 1981
Genus *Vulvulina* d'Orbigny, 1826

Vulvulina miocenica Cushman, 1932

Plate 7, fig. 6

Vulvulina spinosa Cushman var. *miocenica* Cushman, 1932, p. 80, pl. 10, fig. 10.
Vulvulina spinosa Cushman var. *miocenica* Cushman. – Cushman & Todd, 1945, p. 4, pl. 1, fig. 10. – Cushman & Renz, 1947, p. 5, pl. 1, fig. 10. – Renz, 1948, p. 179, pl. 2, fig. 1.
Vulvulina miocenica Cushman. – Kohl, 1985, p. 322, pl. 1, fig. 6.

Occurrence: 4 specimens from 4 samples.

Description: Test large in size, wide, elongate, laterally compressed, initially planispiral, becoming biserial and then uniserial, chambers elongate, increasing in size very rapidly, curved, downward pointing spine at the periphery, sutures limbate, raised, wall coarse, surface rough, aperture a terminal elongate slit.

Remarks: This species has been recorded from the Oligocene to Pliocene from many localities in and around the Gulf of Mexico.

Family PAVONTINIDAE Loeblich & Tappan, 1961
Subfamily SPIROPSAMMININAE Seiglie & Baker, 1984
Genus *Spiropsammina* Seiglie & Baker, 1984

Spiropsammina primula Seiglie & Baker, 1983

Plate 7, fig. 7

Figure: Transmitted light photograph of *Spiropsammina primula* (width 473 μm).

Spiropsammina primula Seiglie & Baker, 1983, pl. 2, figs 7-9.

Occurrence: 4 specimens from 4 samples.

Description: Test rounded in outline, greatly compressed, evolute planispiral, about three coils in total, chambers elongate, increasing in size rapidly as added, curved, containing several alveoles in a fan-like arrangement, wall thin, coarse, surface rough.

Remarks: Originally described from the Middle Miocene offshore Cabinda, this species has been

recorded from many localities offshore West Africa ranging from the Upper Oligocene to Middle Miocene.

Family TROCHAMMINIDAE Schwager, 1877
Subamily TROCHAMMININAE Schwager, 1877
Genus *Portatrochammina* Echols, 1971

Portatrochammina profunda Kender, Kaminski & Jones 2006

Plate 7, figs 8-10

Portatrochammina profunda Kender, Kaminski & Jones, 2006, p. 469, pl. 2, figs 3-8.

Occurrence: 23 specimens from 8 samples.

Description: Test low trochospiral, rounded in outline, three to four whorls in adult, four to four and a half chambers in each whorl, chambers inflated, increase in size rapidly so that the final whorl makes up majority of the test, sutures depressed, wall thin, surface rough with predominantly medium grains containing occasional coarse inclusions.

Remarks: Originally described from the Oligocene section of the well studied in this paper.

Genus *Trochammina* Parker & Jones, 1859

***Trochammina* sp. 1**

Plate 7, fig. 13

Occurrence: 79 specimens from 23 samples.

Description: Test of medium size, consisting of five to six globular chambers trochospirally enrolled and increasing in size gradually, sutures radial, wall thin, coarse, with a rough texture, aperture interiomarginal opening resting on the first chamber of the final whorl.

***Trochammina* sp. 2**

Plate 7, figs 11,12

Occurrence: 2 specimens from 2 samples.

Description: Test high trochospiral, elongate, rounded in section, greatly compressed, about five whorls, three to four chambers in each whorl, chambers inflated, increase in size rapidly, sutures depressed, wall thin, surface rough, aperture an interiomarginal opening.

Remarks: This species differs from *Trochammina altiformis* Cushman & Renz (1946), described from the Upper Cretaceous of the West Indies, in having many more whorls and a higher spire.

***Trochammina* sp. 3**

Occurrence: 151 specimens from 18 samples.

Description: Test very small, trochospiral, chambers increasing gradually in size, sutures radial, periphery rounded, aperture generally unseen, wall fine grained, thin.

Remarks: Differs from *Trochammina* spp. in having a much smaller size and thinner wall.

***Trochammina* sp. 4**

Plate 8, fig. 1

Occurrence: 1 specimen from 1 sample.

Description: Test low trochospiral, rounded in outline, globular, four chambers in the final whorl, chambers inflated, increase in size rapidly, sutures depressed, wall thick, surface rough, aperture an interiomarginal opening with a raised lip.

***Trochammina* spp.**

Occurrence: 32 specimens from 11 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test small to large, trochospiral, chambers increasing gradually in size,

sutures radial, periphery rounded, wall coarse to fine, thin to thick.

Family PROLIXOPLECTIDAE Loeblich & Tappan, 1985

Genus *Eggerelloides* Haynes, 1973

***Eggerelloides* sp. 1**

Plate 8, figs 3,4

Occurrence: 4 specimens from 4 samples.

Description: Test large in size, subfusiform, early stage of growth trochospiral, later triserial, aperture a high interiomarginal arch in the centre of the apertural face, with a broad lip, wall simple, thick, coarse, with a rough texture.

Genus *Karrerulina* Finlay, 1940

Karrerulina apicularis (Cushman, 1911)

Plate 8, figs 5-7

Gaudryina apicularis Cushman, 1911, p. 69, textfig. 110.

Karrerulina apicularis (Cushman). – Loeblich & Tappan, 1987, p. 130, pl. 139, figs 7-13. – Murray & Alve, 1994, pl. 1, fig. 13.

Occurrence: 47 specimens from 23 samples

Description: Test elongate and slender, initially trochospiral, later triserial becoming biserial, chambers slightly inflated, sutures distinct, wall coarse grained, finish rough, aperture terminal, at the end of a projected neck.

Remarks: Originally described from the Recent of the North Pacific, this species is also recorded from the North Atlantic and the Miocene of West Africa.

***Karrerulina* sp.**

Occurrence: 1 specimen from 1 sample.

Description: Test elongate, slender, trochospirally coiled in the initial part and reduced in the latter stages.

Family REOPHACELLIDAE Mikhalevich & Kaminski, 2004

SubfamilyVERNEUILININAE Cushman, 1927

Genus Gaudryina d'Orbigny, 1839

Gaudryina atlantica (Bailey, 1851)

Plate 8, fig. 8

Textularia atlantica Bailey, 1851, p. 12, text-figs 38-43.

Gaudryina atlantica (Bailey). – Cushman, 1922, p. 70, pl. 13, figs 1-3. – Bermúdez, 1949, p. 74, pl. 3, figs 63,64. – Kohl, 1985, p. 33, pl. 3, fig. 7.

Occurrence: 2 specimens from 2 samples

Description: Test large, elongate, triangular in section, initially triserial, later becoming biserial, increasing in size steadily as added, chambers triangular, sutures depressed, wall coarse grained, finish rough, aperture a short slit at the base of the final chamber in the umbilical region.

Remarks: Originally described from the Recent of the Atlantic, this species is also recorded from the Miocene of Puerto Rico and Jamaica.

Family CYCLAMMINIDAE Marie, 1941

Subfamily ALVEOLOPHRAGMIINAE Saidova, 1981

Genus *Reticulophragmium* Maync, 1955

Reticulophragmium acutidorsatum (Hantken, 1868)

Plate 8, fig. 9, Plate 48, figs 1-7

Haplophragmium acutidorsatum Hantken, 1868, p. 82, pl. 1, fig. 1.

Reticulophragmium acutidorsatum (Hantken). – Kaminski & Gradstein, 2005, p. 490, pl. 122, figs 1-7.

Occurrence: 64 specimens from 29 samples

Description: Test large, circular to oval in outline, compressed, planispiral, involute, slightly depressed umbilicus, eight to ten chambers in the final whorl, sutures radial, straight to slightly sigmoidal, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, apertural face contains coarser grains, aperture a long interiomarginal slit, no supplementary areal apertures.

Remarks: Originally described from the Oligocene of Hungary, this species is also recorded in Oligocene to Miocene sediments from the Atlantic, North Sea and Celebes Sea.

***Reticulophragmium acutidorsatum* ssp. 1**

Plate 8, fig. 10

Occurrence: 1 specimen from 1 sample.

Description: Test large, involute planispiral, with twelve chambers in the final whorl, chambers inflated, periphery subacute, sutures depressed at the periphery, radial, straight, angled slightly away from the direction of coiling, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a roughened finish.

Remarks: Differs from *R. acutidorsatum* by having depressed sutures at the margin, and more chambers in the final whorl.

Reticulophragmium amplectens (Grzybowski, 1898)

Plate 8, fig. 11

Cyclammina amplectens Grzybowski, 1898, p. 292, pl. 12, figs 1-3.

Reticulophragmium amplectens (Grzybowski). – Kaminski & Geroch, 1993, p. 266, pl. 11, figs 5-7c.

Reticulophragmium amplectens (Grzybowski). – Kaminski & Gradstein, 2005, p. 495, pl. 123, figs 1-6.

Occurrence: 39 specimens from 15 samples

Description: Test medium size, circular in outline, robust, planispiral, involute, slightly depressed umbilicus, margin subacute, chambers numerous, eight to ten in the final whorl, sutures radial, straight, wall composed of two layers, the inner hypodermal layer is thick and perforated by elongate tubular alveoles, elongate in direction of coiling as observed from the dorsal view, the outer layer is thin and fine-grained, smooth, aperture a long interiomarginal slit, no supplementary areal apertures.

Remarks: Originally described from the Middle Eocene of the Polish Carpathians, this species is known globally from Eocene to Oligocene sediments and extending to Middle Miocene only in the Arctic.

***Reticulophragmium amplectens* ssp. 1**

Plate 9, fig. 1

Occurrence: 3 specimens from 2 samples.

Description: Test large, thick, circular in outline, involute planispiral, periphery subacute, sutures straight, depressed, umbilicus depressed, alveoles

are elongated along to direction of coiling, wall smooth.

Remarks: This form resemblaes *R. acutidorsatum* with its much larger size and less acute periphery, but still show the characteristic elongated alveoles of *R. amplectens*. It therefore may be that *R. amplectens* ssp. 1 evolved from a transitional form of *R. acutidorsatum* due to its close appearance to this form, which would indicate that elongated alveoles evolved more than once and are thus an example of convergent evolution. *R. amplectens* appears first in the Early Eocene.

Reticulophragmium gasparense (Bermúdez, 1949)

Plate 9, fig. 2

Cyclammina gasparensis Bermúdez, 1949, pl. 1, figs 47,48.

Reticulophragmium gasparensis (Bermúdez). – Kender, Kaminski & Jones, in press, pl. 13, fig. 3.

Occurrence: 16 specimens from 11 samples

Description: Test large, circular to oval in outline, compressed, planispiral, involute, margin subacute, about fourteen chambers in the final whorl, increasing in size rapidly as added, apertural face broad and high, sutures radial, straight to slightly sigmoidal, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, aperture a long interiomarginal slit, no supplementary areal apertures.

Remarks: Originally described from the Upper Oligocene of the Dominican Republic. This species differs from *R. acutidorsatum* by having a much larger apertural face.

Reticulophragmium orbiculare (Brady, 1881)

Plate 9, fig. 4

Cyclammina orbicularis Brady, 1881, p. 53.

Cyclammina orbicularis Brady. – Brady, 1884, p. 353, pl. 37, figs 17-18.

Cyclammina rotundidorsata (Hantken). – Jones, 1994, p. 43, pl. 37, figs 20-23.

Reticulophragmium orbicularis (Brady). – Kaminski et al., 2005, p. 390, pl. 7, fig. 2.

Occurrence: 5 specimens from 5 samples

Description: Test large, circular in outline, robust, planispiral, almost as thick as wide, involute, peripheral margin broadly rounded, about fourteen chambers in the final whorl, increasing in size steadily as added, apertural face high and wide, sutures inclined in the direction of growth, straight to slightly curved forwards, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, aperture a long interiomarginal slit, no supplementary areal apertures.

Remarks: Originally described from the Recent of the South Atlantic, has also been recorded from the Miocene of the Fram Strait.

Reticulophragmium rotundidorsatum (Hantken, 1875)

Plate 9, fig. 3, Plate 48, fig. 8

Haplophragmoides rotundodorsatum Hantken, 1875, p. 12, pl. 1, fig. 2.

Cyclammina (Reticulophragmium) rotundidorsatum (Hantken). – Charnock & Jones, 1990, pl. 7, figs. 13-15, pl. 19, fig. 1.

Reticulophragmium rotundidorsatum (Hantken). – Cicha, Rögl, Rupp & Ctyroka, 1998, pl. 5, fig. 5. –

Kaminski & Gradstein, 2005, p. 507, pl. 127, figs 1a-5c.

Occurrence: 19 specimens from 16 samples

Description: Test large, circular in outline, compressed, planispiral, involute, peripheral margin broadly rounded, about eleven chambers in the final whorl, increasing in size steadily as added, sutures radial, straight, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, aperture a long interiomarginal slit, no supplementary areal apertures.

Remarks: Originally described from the Early Oligocene of Hungary, this species has been recorded from the North Sea, Labrador Sea, West Africa and South China Sea from Eocene to Miocene sediments.

***Reticulophragmium* sp. 1**

Occurrence: 37 specimens from 12 samples

Description: Test small, circular in outline, planispiral, involute, chambers numerous, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth.

Remarks: This category contains mostly juvenile forms of *Reticulophragmium* spp.

***Reticulophragmium* spp.**

Occurrence: 36 specimens from 18 samples

Description: Included in this group are all fragmentary, poorly preserved and unassigned forms displaying the following characteristics: test circular in outline, planispiral, involute, chambers numerous, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth.

Family CYCLAMMINIDAE Marie, 1941

Subfamily CYCLAMMININAE Marie, 1941

Genus *Cyclammina* Brady, 1879

***Cyclammina cancellata* Brady, 1879**

Plate 9, figs 5,6

Cyclammina cancellata Brady, 1879, p. 62.

Cyclammina cancellata Brady. – Brady, 1884, pl. 37, figs 8-15. – Kaminski & Gradstein, 2005, p. 476, pl. 118, figs 1-4.

Occurrence: 2 specimens from 2 samples

Description: Test very large, circular to oval in outline, robust, planispiral, involute, margin rounded, fourteen to sixteen chambers in the final whorl, increasing in size rapidly as added, apertural face broad and high, sutures radial, sigmoidal, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, apertural face contains coarse grains, aperture a long interiomarginal slit, supplementary areal apertures numerous, each surrounded by a raised lip.

Remarks: Originally described from the Recent of the North Atlantic, this species is a cosmopolitan form described from sediments ranging from the Late Eocene to Recent, although it is possible that early forms would here be classified under *C. cancellata* ssp. 1.

***Cyclammina cancellata* ssp. 1**

Plate 9, fig. 7

Occurrence: 2 specimens from 2 samples

Description: Test very large, circular to oval in outline, robust, planispiral, involute, margin rounded, fourteen to sixteen chambers in the final whorl, increasing in size rapidly as added, apertural face broad and high, sutures radial, sigmoidal, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, circular in appearance from the dorsal view, the outer layer is thin and fine-grained, smooth, apertural face contains coarse grains, aperture a long interiomarginal slit, about eight supplementary areal apertures arranged in a circle, each surrounded by a raised lip.

Remarks: This species differs from C. cancellata in having fewer supplementary apertures arranged in a circle.

***Cyclammina* sp. 1**

Plate 10, figs 1-3

Cyclammina (Cyclammina) acutidorsata (Hantken). – Charnock & Jones, 1997, p. 188, fig. 6, figs 2a-c.

Occurrence: 2 specimens from 2 samples.

Description: Test large, involute, planispiral, with twelve to fourteen chambers in the final whorl, test approximately half as thick as wide, periphery subacute, sutures depressed, sigmoidal in later stages, umbilicus depressed, apertural face large, convex, containing coarse grains, primary aperture is a basal slit covered by a small lip, a single round supplementary aperture is present in the centre of the apertural face, sometimes surrounded by a raised lip, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks: This species is distinct due to its single supplementary aperture in the centre of the apertural face, and differs from *C. cyclops* McNeil (1988) by having a much thicker test, larger apertural face and more involute coiling. Charnock & Jones (1997) also illustrate this species from the North Sea, and class it under the name *C. acutidorsata*, along with other specimens containing more supplementary apertures but with an otherwise similar morphology.

***Cyclammina* sp. 2**

Plate 10, fig. 4, Plate 11, figs 1-5

Cyclammina sp. Kaminski, Silye & Kender, 2005, p. 395, pl. 7, figs 3a-c.

Occurrence: 3 specimens from 2 samples.

Description: Test large, involute, planispiral, with ten to thirteen chambers in the final whorl, test approximately half as thick as it is wide, periphery acute, sutures depressed and sigmoidal in later stages, umbilicus depressed, apertural face large, convex, containing coarse grains, primary aperture is a basal slit covered by a small lip, three to four round supplementary apertures are present in the centre of the apertural face formed in a diamond arrangement, each surrounded by raised lips, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks: This species is distinct due to its three to four supplementary apertures on the apertural face arranged as an oblique 'diamond'. Charnock & Jones (1997) have found similar cyclamminids from the North Sea and generally classed them under *C. acutidorsata.*

***Cyclammina* spp.**

Occurrence: 36 specimens from 17 samples.

Description: Included in this group are all fragmentary, poorly preserved and unassigned forms displaying the following characteristics: test large, involute, planispiral, sutures depressed and sigmoidal in later stages, apertural face large, convex, containing coarse grains, wall composed of two layers, the inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Family EGGERELLIDAE Cushman, 1937

Subfamily DOROTHIINAE Balakhmatova, 1972

Genus *Dorothia* Plummer, 1931

Dorothia brevis Cushman & Stainforth, 1945

Plate 11, figs 6,7

Dorothia brevis Cushman & Stainforth, 1945, p. 18, pl. 2, fig. 5.

Dorothia brevis Cushman & Stainforth. – Kurihara & Kennett, 1986, p. 1069, pl. 1, fig. 10.

Occurrence: 2 specimens from 2 samples.

Description: Test biserial, inflated, almost as wide as high, initial end acute, chambers inflated, increasing is size rapidly as added, sutures slightly depressed, wall smooth, containing a high proportion of cement, aperture at the base of the final chamber, an elongate slit covered by a lip.

Remarks: Originally described from the Oligocene of Trinidad, this species has also been recorded from the Miocene of the South Pacific.

Subfamily EGGERELLINAE Cushman, 1937

Genus *Eggerella* Cushman, 1935

Eggerella bradyi (Cushman, 1911)

Plate 12, figs 1,2

Verneuilina bradyi Cushman, 1911, p. 54, text-fig. 87.

Eggerella bradyi (Cushman). – Cushman, 1937a, p. 52, pl. 5, fig. 19. – Kohl, 1985, p. 32, pl. 3, fig. 3.

Occurrence: 11 specimens from 8 samples.

Description: Test trochospiral becoming triserial, elongate, chambers inflated, increasing in size rapidly as added, sutures depressed, wall smooth, containing a high proportion of cement, aperture at the base of the final chamber, an elongate slit surrounded by a lip.

Remarks: Originally described from the Recent of Atlantic and Pacific, this species is cosmopolitan and has also been recorded from the Miocene.

Genus *Karreriella* Cushman, 1933

Karreriella* aff. *bradyi (Cushman, 1911)

Plate 12, figs 3,4

Gaudryina bradyi Cushman, 1911, p. 67, text-fig. 107.

Karreriella bradyi (Cushman). – Cushman, 1937a, p. 135, pl. 16, figs 6-11.

Occurrence: 2 specimens from 1 sample.

Description: Test triserial becoming biserial, elongate, tapering towards the apical end, chambers inflated, initially increasing in size rapidly as added, then only slowly, sutures depressed, wall smooth, containing a high proportion of cement, aperture near the base of the final chamber, an oval opening surrounded by a lip.

Remarks: Originally described from the Recent of Atlantic and Pacific, this species is cosmopolitan and has also been recorded from the Miocene. Our speimens differ from the original pictured by Cushman in not having a slit-like aperture.

However the type description stipulates "aperture oval ... with a border raised ... and thickened", which does fit with our specimens.

Karreriella microgranulosa Graham, de Klasz & Rérat, 1965

Plate 12, figs 5-7

Karreriella microgranulosa Graham, de Klasz & Rérat, 1965, p. 77, pl. 2, fig. 1.

Occurrence: 12 specimens from 8 samples.

Description: Test small, triserial becoming biserial, elongate, tapering towards the apical end, chambers compact, strongly overlapping, initially increasing in size rapidly as added, then only slowly, sutures only slightly depressed, becoming more so in later portion, wall smooth, containing a high proportion of cement, aperture near the base of the final chamber, a circular opening surrounded by a lip.

Remarks: Originally described from the Lower Miocene of Gabon.

Remarks: Differs from *K.* aff. *bradyi* in having a much smaller size and not inflated chambers.

Genus Martinotiella Cushman, 1933

Martinotiella communis (d'Orbigny, 1846)

Plate 12, figs 8-10

Clavulina communis d'Orbigny, 1846, p. 196, pl. 12, figs 1,2.

Martinotiella communis (d'Orbigny). – Asano, 1950, p. 3, figs 16,17. – Kohl, 1985, p. 33, pl. 4, fig. 2. – Cicha et al., 1998, p. 111, pl. 9, figs 6,7.

Occurrence: 3 specimens from 3 samples.

Description: Test triserial becoming biserial and uniserial, uniserial portion making up the majority of test, elongate, chambers slightly inflated, initially increasing in size rapidly as added, then only slowly, sutures depressed, wall coarse, containing a high proportion of cement, surface roughened, aperture a terminal round opening, ain the centre of the final chamber.

Remarks: This species has only been recovered as fragments of the uniserial portion of test. *M. communis* is a cosmopolitan species ranging from the Miocene to Recent.

***Martinotiella* sp.**

Plate 12, fig. 11

Occurrence: 1 specimen from 1 sample.

Description: Fragmentary test uniserial, probably triserial initial part lost, uniserial portion elongate, chambers slightly inflated, increasing in size rapidly as added, sutures depressed, wall coarse, containing a high proportion of cement, surface roughened, aperture a terminal round opening, ain the centre of the final chamber.

Remarks: Differs from *M. communis* in having a strongly tapering uniserial portion.

Family VALVULINIDAE Berthelin, 1880

Subfamily VALVULININAE Berthelin, 1880

Genus *Valvulina* d'Orbigny, 1826

Valvulina flexilis Cushman & Renz, 1941

Plate 12, figs 12,13

Valvulina flexilis Cushman & Renz, 1941, p. 7, pl. 1, figs 16-17.

Valvulina flexilis Cushman & Renz. – Cushman & Stainforth, 1945, p. 17, pl. 2, fig. 4. Cushman & Renz, 1948, p. 177, pl. 2, fig. 12. – Renz, 1948, p. 177, pl. 2, figs 11-12. – Green et al., 2004, p. 129, pl. 7, figs 4-6.

Occurrence: 29 specimens from 16 samples.

Description: Test small to large, triserial, later becoming biserial, elongate tapering, chambers

inflated, almost sac-like, increasing in size rapidly, sutures depressed, wall coarse, with a rough texture, aperture an interiomarginal opening at the base of the final chamber, with a projecting tooth.

Remarks: Originally described from the Oligocene and Miocene of Venezuela, this species has also been recorded from the Miocene of the Gulf of Mexico and offshore West Africa.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus *Bigenerina* d'Orbigny, 1826

***Bigenerina* sp.**
Plate 12, fig. 14

Occurrence: 1 specimen from 1 sample.

Description: Test small, elongate, biserial becoming uniserial, chambers inflated, sutures depressed, wall canaliculated, coarse, surface rough, aperture a terminal rounded opening.

Genus *Textularia* Defrance, 1824

Textularia earlandi Parker, 1952
Plate 12, fig. 15

Textularia tenuissima Earland, 1933, p. 95, pl. 3, figs 21-30.
Textularia earlandi Parker, 1952, p. 458.

Occurrence: 1 specimen from 1 sample.

Description: Test small biserial, elongate, usually broken, chambers very numerous, slightly inflated, increasing in size only slowly with growth, sutures depressed, wall thin, fine-grained, with a roughish texture, aperture a curved opening at the base of the final chamber.

Remarks: Originally described from the Recent, this is a cosmopolitan species. It probably contains an organic wall as it occurs in samples devoid of calcareous forms, which suggests that it should actually be placed in a different genus.

Family OPTHALMIDIDAE Wiesner, 1920
Genus *Opthalmidium* Kubler & Zwingli, 1870

***Opthalmidium* species A** Kohl, 1985
Plate 13, fig. 1

Opthalmidium species A Kohl, 1985, pl. 4, figs 8-10.

Occurrence: 2 specimens from 2 samples.

Description: Test planispiral, strongly compressed, fusiform in shape, length twice that of the width, chambers half coil in length, each one initially thicker and becoming thinner towards the terminus, chambers added regularly to form 12 to 14 in adult, wall porcellaneous, smooth, aperture a terminal rounded opening.

Remarks: *Opthalmidium* sp. A was reported as rare in the Pliocene of the Salina Basin by Kohl (1985).

Family SPIROLOCULINIDAE Wiesner, 1920
Genus *Spiroloculina* d'Orbigny, 1826

Spiroloculina excavata d'Orbigny, 1846
Plate 13, fig. 2

Spiroloculina excavata d'Orbigny, 1846, p. 271, pl. 16, figs 19-21.
Spiroloculina dilatata d'Orbigny, 1846, p. 271, pl. 16, figs 16-18.

Occurrence: 2 specimens from 2 samples.

Description: Test planispiral, compressed, almost as wide as long, coiling spiroloculine, chambers increasing in size gradually, aperture terminal at the end of a slightly protruding neck.

Remarks: Specimens of this species are poorly preserved such that margin and aperture of test is

not observed. Papp & Schmid (1985) record a sharply marginated last coil and the presence of an apertural tooth.

Subfamily HAURININAE Schwager, 1876
Genus *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina triloculiniforma McLean, 1956
Plate 13, fig. 3

Quinqueloculina triloculiniforma McLean, 1956, p. 322, pl. 37, figs 9-11.

Occurrence: 2 specimens from 2 samples.

Description: Test large, round in outline, coiling quinqueloculine so that four chambers are visible from one side and three from the other, chambers inflated, rounded, increasing in size rapidly, wall smooth, aperture terminal, large, with a broad simple tooth.

Quinqueloculina triangularis d'Orbigny, 1846
Plate 13, fig. 4

Quinqueloculina triangularis d'Orbigny, 1846, p. 288, pl. 18, figs 7-9.

Quinqueloculina triangularis d'Orbigny. – Łuczkowska, 1974, p. 63, pl. 8, figs 4-5, pl. 9, fig. 1, text fig. 23.

Occurrence: 2 specimens from 2 samples.

Description: Test rounded elongate in outline, distinctly triangular in section, coiling quinqueloculine so that four chambers are visible from one side and three from the other, chambers inflated, rounded, increasing in size rapidly, wall smooth.

Remarks: Specimens of this species are poorly preserved such that the aperture of test is not observed. Papp & Schmid (1985) record a large terminal apertural with a distinct tooth.

Subfamily MILIOLINELLINAE Vella, 1957
Genus *Pyrgo* Defrance, 1824

Pyrgo magnacaudata Smith, 1948
Plate 13, fig. 5

Pyrgo magnacaudata Smith, 1948, p. 58, pl. 11, figs 14-16.

Occurrence: 1 specimen from 1 sample.

Description: Test bulbous, small, outline almost spherical, two chambers visible, inflated, increasing in size as added, appendage at basal portion of final chamber is broad, thick, with parallel sides, surface smooth, aperture large, with thickened rim and wide tooth.

***Pyrgo* spp.**
Plate 13, fig. 6

Occurrence: 3 specimens from 2 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test bulbous, outline rounded, two chambers visible, inflated, increasing in size as added, sometimes has appendage at basal portion of final chamber, surface smooth, terminal aperture.

Subfamily SIGMOILINITINAE Łuczkowska, 1974
Genus *Sigmoilinita* Seiglie, 1965

Sigmoilinita elliptica (Galloway & Wissler, 1927)
Plate 14, fig. 1

Sigmoilina elliptica Galloway & Wissler, 1927, p. 39, pl. 7, figs 2a-b.

Sigmoilina miocenica Cushman, 1946, p. 33, pl. 5, figs 19-22.

Sigmoilinita elliptica (Galloway & Wissler). Kohl, 1985, pl. 5, fig. 4.

Occurrence: 4 specimens from 4 samples.

Description: Test free, slightly compressed, oval in outline, length one and a half to two times the width, coiling triloculine becoming biloculine, with chambers added at slightly more than 180° from one another forming a sigmoidal curve, chambers inflated, elongate and narrow, sutures slightly depressed, aperture a terminal circular opening at the end of a projected neck.

Remarks: Differs from *S. tenuis* in its less distinct sutures and less compressed form.

Sigmoilinita tenuis (Czjzek, 1848)

Plate 14, fig. 2

Quinqueloculina tenuis Czjzek, 1848, p. 149, pl. 13, figs 31-34

Spiroloculina tenuissima Reuss, 1867, p. 71, pl. 1, fig. 11.

Sigmoilina tenuis (Czjzek). Cushman & Todd, 1945, p. 10, pl. 2, fig. 4.

Sigmoilinita tenuis (Czjzek). Kohl, 1985, pl. 5, fig. 5.

Occurrence: 1 specimen from 1 sample.

Description: Test small, compressed, oval in outline, length one and a half times the width, coiling triloculine becoming biloculine, with chambers added at slightly more than 180° from one another forming a sigmoidal curve, chambers elongate and narrow, sutures distinct, aperture a terminal circular opening at the end of a projected neck.

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus *Chrysalogonium* Schubert, 1908

Chrysalogonium lanceoleum Cushman & Jarvis, 1934

Plate 14, fig. 3

Chrysalogonium lanceoleum Cushman & Jarvis, 1934, p. 75, pl. 10, fig. 16

Chrysalogonium lanceoleum Cushman & Jarvis. – Cushman & Stainforth, 1945, p. 25, pl. 3, fig. 29, pl. 16, fig. 5. – Beckmann, 1953, p. 352, pl. 19, fig. 9. – Bolli et al., 1994, p. 256, pl. 63, fig. 26, p. 317, pl. 87, fig. 35.

Occurrence: 13 specimens from 5 samples.

Description: Test small, elongate, uniserial, rectilinear, initial chambers short in length, sutures indistinct so that surface is completely smooth, wall thick.

Remarks: Specimens of this species are not common but occur persistently. Only the first few chambers are ever preserved so that full adult test is not observed. Bolli et al. (1994) picture adult forms with eight chambers increasing in length and breadth very gradually, sutures becoming more depressed, aperture terminal.

***Chrysalogonium* sp.1**

Plate 14, fig. 4

Occurrence: 4 specimens from 2 samples.

Description: Test uniserial, elongate, chambers spherical to slightly elongate, changing in size and shape as added, sutures depressed, wall smooth, covered in numerous fine longitudinal costae extending sometimes the full length of test, aperture terminal.

Genus *Nodosaria* Lamark, 1812

Nodosaria anomala Reuss, 1866

Plate 14, fig. 5

Nodosaria anomala Reuss, 1866, p. 129, pl. 1, figs 20-22 (fide Ellis & Messina, 1940).

Occurrence: 12 specimens from 9 samples.

Description: Test uniserial, elongate, consisting of up to seven rectilinear chambers, chambers globular, generally spherical to ovoid, increasing in size slowly, overlapping the previous one to varying degrees so as to give a somewhat irregular appearance, sutures usually constricted, wall smooth, aperture a terminal round opening.

Remarks: Originally described from the Oligocene of Germany.

Nodosaria glandulinoides Neugeboren, 1852

Plate 14, fig. 6

Nodosaria glandulinoides Neugeboren, 1852, p. 37, pl. 1, fig. 2.

Nodosaria sp. (?). Cushman & Jarvis, 1930, p. 361, pl. 33, fig. 2.

Occurrence: 2 specimens from 1 samples.

Description: Test elongate, uniserial, rectilinear, chambers inflated, spherical in outline, three to four slightly overlapping, constricted at sutures, final chamber slightly elongated and tapering towards terminal aperture.

Remarks: These specimens have a poorly preserved aperture. Kohl (1985) describes a radiate aperture, covered with a plate-like process held aloft by eight solid bars.

Nodosaria pyrula d'Orbigny, 1826

Plate 14, fig. 7

Nodosaria pyrula d'Orbigny, 1826, p.253, fig. 13 (fide Ellis & Messina, 1940).

Nodosaria pyrula d'Orbigny. –Macfadyen, 1930, pl. 2, fig. 16. – Akers & Doorman, 1964, pl.6, fig. 19. – Papp & Schmid, 1985, pl. 4, figs 2-3. – Kohl, 1985, pl.6, fig. 4. Filipescu, 1996, pl. 1, fig. 5.

Nodosaria cf. pyrula d'Orbigny. – Cushman & Stainforth, 1945, pl. 3, fig. 22.

Grigelis pyrula (d'Orbigny). – Cicha et al., 1998, pl. 21, fig. 9.

Occurrence: 5 specimens from 3 samples.

Description: Test elongate, uniserial, rectilinear, chambers circular in section, tapered at either end to form pear-shaped outline, separated by long tubular neck, wall smooth, aperture terminal.

Remarks: Poor preservation obscures certain characteristics. Papp & Schmid (1985) pictures specimens with up to seven chambers, straight to slightly arcuate in outline and with sometime spherical chambers. Kohl (1985) describes the aperture as radiate, with six to seven connected bars atop a circular opening.

***Nodosaria* spp.**

Plate 14, fig. 8

Occurrence: 21 specimens from 9 samples.

Description: Included in this group are all fragmentary and unassigned forms displaying the following characteristics: test uniserial, elongate, rectilinear, with chambers spherical to elongate in outline.

Subfamily PLECTOFRONDICULARIINAE Cushman, 1927

Genus *Amphimorphina* Neugeboren, 1850

Amphimorphina stainforthi (Cushman & Renz, 1941)

Plate 14, figs 9-11

Nodosaria stainforthi Cushman & Renz, 1941, pl. 3, fig. 4.

Nodosaria stainforthi Cushman & Renz. – Cushman & Renz, 1947, pl. 4, fig. 20. – Renz, 1948, pl. 4, fig. 31. – Blow, 1959, p. 128. – Petters, 1982, pl. 5, fig. 34.

Amphimorphina stainforthi (Cushman & Renz). – Kohl, 1985, pl. 9, figs 4-5.

Pyramidulina stainforthi (Cushman & Renz). – Bolli et al., 1994, pl. 63, fig. 18, pl. 77, figs 39-40.

Occurrence: 32 specimens from 12 samples.

Description: Test uniserial, elongate, rectilinear, chambers spherical to hexagonal in section, numerous, increasing in size rapidly and becoming inflated, sutures horizontal and depressed, wall smooth, ornamented with six to seven wide longitudinal costae extending the length of test and thickened at the sutures, aperture terminal, central.

Remarks: Kohl (1984) describes and pictures the aperture as the opening in between a radiate series of ten to fourteen ribs extending inward from a thickened polygonal rim.

Subfamily LENTICULININAE Chapman, Parr & Collins, 1934

Genus *Lenticulina* Lamark, 1804

Lenticulina americana (Cushman, 1918)

Plate 14, figs 12,13

Cristellaria americana Cushman, 1918, pl. 10, figs 5-6.

Robulus americanus (Cushman). – Cushman, 1930, pl. 3, fig. 7. – Cushman & Cahill, 1933, pl. 3, fig. 6. – Renz, 1948, pl. 12, fig. 3. – Blow, 1959, p. 130-131.

Lenticulina americana (Cushman). – Bermúdez & Fuenmayor, 1966, pl. 3, figs 9-10. – Petters, 1982, pl. 4, fig. 16. – Bolli et al, 1994, pl. 77, fig. 5.

Lenticulina (Robulus) americanus (Cushman). – Whittaker, 1988, pl. 5, figs 1-2.

Occurrence: 37 specimens from 16 samples.

Description: Test involute planispiral, biconvex, subcircular in outline, periphery finely keeled, chambers increasing in size gradually, six to seven in the final whorl, sutures limbate, slightly raised and curved, wall smooth, aperture radiate, with a slit projecting down onto the upper part of the apertural face.

Lenticulina calcar (Linnaeus, 1758)

Plate 14, fig. 14

Nautilus calcar Linnaeus, 1758, p. 709.

Robulina calcar (Linnaeus). – d'Orbigny, 1846, p. 99, pl. 4, figs 18-20. – Renz, 1948, pl. 3, fig. 6.

Cristellaria calcar (Linnaeus). – Nuttall, 1928, pl. 5, fig. 8. – Macfadyen, 1930, pl. 3, fig. 17.

Lenticulina calcar (Linnaeus). – Kohl, 1985, pl. 10, figs 4-5, – Papp & Schmid, 1985, pl. 30, figs 1-3. – Bolli, 1994, p. 294, pl. 77, fig. 5.

Occurrence: 4 specimens from 4 samples.

Description: Test involute planispiral, biconvex, subcircular in outline, periphery keeled, with extended delicate spines opposite chambers, chambers increasing in size gradually, five to seven in the final whorl, sutures limbate, slightly curved, smooth with surface of the test, wall smooth, aperture radiate, with a slit projecting down onto the upper part of the apertural face.

Remarks: *Lenticulina calcar* is a cosmopolitan species described from many localities around the Atlantic and Pacific from the Miocene to Holocene, and is rare in most localities.

Lenticulina formosa (Cushman, 1923)

Plate 15, fig. 1

Cristellaria formosa Cushman, 1923, p. 110, pl. 29, fig. 1, pl. 30, fig. 6.

Lenticulina formosa (Cushman). – Hadley, 1934, p. 11, pl. 1, fig. 11. – Barker, 1960, p. 146, pl. 70, figs 13-15.

Robulus formosus (Cushman). – Bermúdez, 1949, p.126, pl. 6, figs 57-58.

Occurrence: 16 specimens from 3 samples.

Description: Test large, involute planispiral, biconvex, subcircular in outline, periphery keeled, with thin spines protruding out, chambers increasing in size gradually, eight to twelve in the final whorl, sutures limbate, slightly curved, raised from surface of the test, wall smooth, aperture radiate, with a slit projecting down onto the upper part of the apertural face.

Remarks: *Lenticulina formosa* is a cosmopolitan species described from Miocene to Holocene localities from the Atlantic and Pacific, and is usually rare.

Lenticulina* aff. *multinodosa Schijfsma, 1946

Plate 14, fig. 15, Plate 15, fig. 2

Lenticulina multinidosa Schijfsma, 1946, p. 57, pl. 3, fig. 10.

Occurrence: 4 specimens from 4 samples.

Description: Test large, involute planispiral, biconvex, subcircular in outline, periphery undulate, chambers increasing in size gradually, ten to twelve in the final whorl, sutures radiate to slightly curved, greatly thickened at margin, raised high from surface of the test giving a 'humped' appearance at the periphery, wall smooth, aperture radiate.

Remarks: This species is very similar to true *Lenticulina multinodosa* described by Schijfsma (1946) from the Upper Cretaceous of southern Limburg, Netherlands. Specimens in this study may be closely related, but appear to have more chambers than the eight to ten originally described. Species of *Lenticulina* with this morphology have not been described from other localities in the Atlantic.

Genus *Saracenaria* Defrance, 1824

***Saracenaria* sp.**

Plate 15, fig. 3

Occurrence: 1 specimen from 1 sample.

Description: Test initially planispiral, becoming flared to almost rectilinear, periphery rounded, apertural face broad, flat, sutures slightly curved, depressed, surface smooth, aperture radiate.

Remarks: The single specimen is poorly preserved and abraded, hampering identification.

Family LAGENIDAE Reuss, 1862

Genus *Pygmaeoseistron* Patterson & Richardson, 1987

***Pygmaeoseistron* spp.**

Plate 15, fig. 4

Occurrence: 6 specimens from 3 samples.

Description: Test elongate, uniserial, rectilinear, consisting of straight series of globular spherical chambers attached by thin tubular necks, aperture terminal round opening.

Remarks: All specimens are fragmentary and poorly preserved, making identification of species difficult.

Subfamily GLANDULININAE Reuss, 1860

Genus *Glandulina* d'Orbigny, 1839

Glandulina ovula d'Orbigny, 1846

Plate 15, fig. 5,6

Glandulina ovula d'Orbigny, 1846, p. 29, pl. 1, figs 6-7.

Occurrence: 2 specimens from 2 samples.

Description: Test elongate, uniserial in megalospheric forms, biserial rapidly becoming uniserial in microspheric forms, circular in section, ovate in outline, tapering towards both ends, chambers initially increasing rapidly in size, strongly overlapping previous chambers, sutures straight, distinct, flush with surface, up to six visible in adult form, surface of test smooth, aperture terminal, central, with seven to eight bars converging to a point above the circular opening.

Remarks: Originally described from the Oligocene-Miocene of the Vienna basin, is distinguished from *G. laevigata* d'Orbigny by the lack of a pointed base, and possessing fewer radiating ribs at the aperture.

Subfamily CERATOBULIMININAE Cushman, 1927

Genus *Ceratobulimina* Toula, 1915

Ceratobulimina alazanensis Cushman & Harris, 1927

Plate 15, fig. 7

Ceratobulimina alazanensis Cushman & Harris, 1927, p. 174, pl. 29, figs 5a-c. – Whittaker, 1988, p. 110, pl.14, figs 14-16. – Robertson, 1998, p. 123, pl. 44, figs 1a-c.

Occurrence: 2 specimens from 2 samples.

Description: Test trochospiral, rounded to ovate in outline, chambers inflated, periphery rounded, five chambers in the final whorl increasing in size rapidly, sutures distinct, depressed, curved, surface smooth, aperture an elongate slit extending from the umbilicus to half way up the apertural face.

Remarks: Originally described from the Upper Oligocene of Mexico, this form has also been recorded from the Middle Miocene of Jamaica.

Subfamily EPISOMININAE Wedekind, 1937

Genus *Hoeglundina* Brotzen, 1948

Hoeglundina elegans (d'Orbigny, 1826)

Plate 15, figs 8,9, Plate 16, fig. 1

Rotalia (Turbinulina) elegans d'Orbigny, 1826, p. 276 (fide Ellis & Messina, 1940)

Rotalina partschiana d'Orbigny, 1846, p. 153, pl. 7, figs 28-30, pl. 8, figs 1-3.

Epistomina elegans (d'Orbigny). – Cushman & Jarvis, 1930, p. 365, pl. 34, figs 1a-c.

Hoeglundina elegans (d'Orbigny). – Bermúdez, 1949, p. 250, pl. 17, figs 34-36. – Kohl, 1985, p. 59, pl. 14, figs 4-5. – Van Morkhoven et al., 1986, p. 97, pl. 29, figs 1-2.

Occurrence: 27 specimens from 17 samples.

Description: Test trochospiral, circular in outline, biconvex, umbilical side involute, spiral side evolute, periphery acute, chambers distinct, increasing in size gradually, seven to nine in the final whorl, sutures flush with surface or slightly raised, straight, surface smooth, hyaline, aperture a marginal slit extending along the margin of the final chamber, infilled and closed in older chambers, secondary aperture a round opening at the base of the apertural face.

Remarks: Common cosmopolitan form recorded from Europe, the Atlantic, Pacific and Indian Oceans, ranging from Late Eocene to Pleistocene.

Family BOLIVINIDAE Glaessner, 1937

Genus *Bolivina* d'Orbigny, 1839

Bolivina multicostata (Cushman, 1918)

Plate 16, fig. 2

Bolivina aenariensis (Costa) var. *multicostata* Cushman, 1918, pl. 10, fig. 2.

Bolivina marginata var. *multicostata* (Cushman). – Cushman, 1930, pl. 8, figs 13-14. – Cushman & Cahill, 1933, pl. 8, fig. 10. – Cushman, 1937b, pl. 10, figs 7-10. – Cushman & Renz, 1947, pl. 6, fig. 10. – Renz, 1948, pl. 7, figs 6-8.

Bolivina marginata multicostata (Cushman). – Blow, 1959, p. 146. – Bolli et al., 1994, pl. 53, figs 8-9, pl. 78, figs 14-16.

Bolivina multicostata (Cushman). – Whittaker, 1988, pl. 11, figs 10-13. – Finger, 1992, pl. 17, fig. 56.

Occurrence: 24 specimens from 10 samples.

Description: Test biserial, elongate, three times as long as wide, initial end rounded in outline, sides becoming almost parallel, compressed in edge view, margin slightly carinate, chambers numerous, sutures curved and depressed, several longitudinal costae, some running the full length of test, occasionally bifurcating and anastomosing, wall finely perforate, aperture extending from the base of final chamber with a tooth plate.

Remarks: This species has been reported from various localities in Miocene of the Gulf of Mexico.

Bolivina tenuisstriata Cushman & Ellisor, 1939

Plate 16, fig. 3

Bolivina tenuisstriata Cushman & Ellisor, 1939, pl. 1, fig. 8.

Occurrence: 45 specimens from 6 samples.

Description: Test biserial, elongate, two to three times as long as wide, initial end rounded in outline, sides becoming almost parallel, compressed in edge view, margin acute, eight to nine chamber pairs, sutures curved and depressed, numerous longitudinal striae cover the surface, wall perforate, aperture extending from the base of final chamber with a tooth plate.

Genus *Brizalina* Costa,1856

Brizalina alazanensis (Cushamn, 1926)

Plate 16, figs 4,5, Plate 49, figs 1-3

Bolivina alazanensis Cushamn, 1926, pl. 12, fig. 1.

Bolivina alazanensis (Cushamn). – Cushman, 1937b, pl. 8, figs 6-7. – Renz, 1948, pl. 12, fig. 7. – Blow, 1959, p. 144. – Bolli et al., 1994, pl. 53, figs 2-3, pl. 78, fig. 3.

Occurrence: 565 specimens from 31 samples.

Description: Test biserial, elongate, two to three times as long as wide, initial end rounded to semi acute in outline, sides tapering to near parallel, compressed in edge view, margin acute to slightly carinate, chambers numerous, about seven pairs visible, sutures curved and depressed, surface smooth, wall perforate, aperture extending from the base of final chamber with a tooth plate.

Brizalina* cf. *barbata (Phleger & Parker, 1951)

Plate 16, figs 6-8

Bolivina barbata Phleger & Parker, 1951, p. 13, pl. 6, figs 12-13.

Bolivina barbata Phleger & Parker. – Andersen, 1961, p. 93, pl. 20, fig. 6. – Akers & Doorman, 1964, p. 24, pl. 8, fig. 34.

Brizalina barbata (Phleger & Parker). – Kohl, 1985, pl. 17, fig. 7.

Occurrence: 485 specimens from 24 samples.

Description: Test biserial, elongate, up to four times as long as wide in adult, initial end acute in outline, sides becoming almost parallel, compressed in edge view, margin slightly carinate, chambers numerous, about thirteen pairs in adult, ending in sharp downward pointing projections to give a 'serrated' outline, sutures curved and depressed, slightly inflated, wall smooth and very

finely perforate, aperture extending from the base of final chamber with a tooth plate.

Remarks: *Brizalina* cf. *barbata* exhibits close affinities to true *B. barbata* described from the Holocene of the Gulf of Mexico, but differs from the latter in having a much finer perforate wall and a smaller proloculus. *B. barbata* is not known from the Miocene.

Brizalina* aff. *inflata (Heron-Allen & Earland, 1913)

Plate 16, fig. 9

Bolivina inflata Heron-Allen & Earland, 1913, p. 68, pl. 4, figs 19-16.

Bolivina inflata Heron-Allen & Earland. – Cushman, 1937b, p. 166, pl. 18, fig. 16.

Brizalina inflata (Heron-Allen & Earland). – Kohl, 1985, pl. 17, fig. 9.

Occurrence: 130 specimens from 20 samples.

Description: Test biserial, elongate, twice as long as wide, initial end rounded in outline, sides becoming almost parallel, slightly compressed in edge view, margin rounded, chambers numerous, slightly inflated, five to nine pairs in adult, sutures straight, depressed, wall smooth and very finely perforate, aperture extending from the base of final chamber with a tooth plate.

Remarks: Original species described from the Holocene of the British Isles, the specimens in this report differ by having more parallel sides and a slightly higher apertural face.

Subfamily CASSIDULININAE d'Orbigny, 1839

Genus *Cassidulinella* d'Orbigny, 1826

Cassidulinella pliocenica Natland, 1940

Plate 16, fig. 10

Cassidulinella pliocenica Natland, 1940, p. 568, *Cassidulinella pliocenica* Natland. – Loeblich & Tappan, 1987, pl. 554, figs 11-14.

Occurrence: 25 specimens from 14 samples.

Description: Test subcircular in outline, flattened in side view, biserial, chambers inflated, increasing in size rapidly as added, six pairs in the adult form, biserially enrolled in the early stage, becoming flared and elongated, final chamber encompassing nearly half the circumference of the test, wall smooth, finely perforate, aperture a long slit at the periphery of the final chamber.

Remarks: Always preserved as pyrite internal moulds. This is the type species of *Cassidulinella*, and was originally described from the Upper Pliocene of California.

Genus *Globocassidulina* Voloshinova, 1960

Globocassidulina punctata Berggren & Miller, 1986

Plate 16, figs 11,12

Globocassidulina punctata Berggren & Miller, 1986 (*in* Van Morkhoven et al., 1986), p. 119, pl. 37, fig. 1.

Occurrence: 46 specimens from 14 samples.

Description: Test subglobular, slightly tapering at on end, small, rounded in section, chambers inflated, biserially arranged, four two five pairs visible in adult increasing gradually in size, sutures slightly depressed, limbate, wall coarsely perforate, smooth, aperture an elongate slit in a depression on the apertural face, straight to slightly curved, lip attached to outer margin, elongate tooth.

Remarks: Distinguished from *G. subglobosa* by the presence of a more perforated wall, and generally smaller dimensions. Described originally from the Gulf of Mexico, Early to Late Miocene.

Globocassidulina subglobosa (Brady, 1881)

Plate 17, figs 1,2

Cassidulina subglobosa Brady, 1881, p. 60.

Cassidulina subglobosa Brady. – Brady, 1884, p. 430, pl. 54, fig. 17. – Cushman & Todd, 1945, p. 61, pl. 10, fig. 8. – Renz, 1948, p. 125, pl. 9, figs 11-12. – Phleger & Parker, 1951, p. 27, pl. 14, figs 11-12

Globocassidulina subglobosa (Brady). – Belford, 1966, p. 149, pl. 25, figs 11-16. – LeRoy & Levinson, 1974, p. 14, pl. 7, fig. 8.

Occurrence: 22 specimens from 10 samples.

Description: Test subglobular, rounded in section, periphery rounded, chambers inflated, biserially arranged, four two five pairs visible in adult increasing gradually in size, sutures slightly depressed, wall finely perforate, smooth, aperture an elongate slit in a depression on the apertural face, lip attached to outer margin, elongate tooth.

Remarks: G. subglobosa is a cosmopolitan species described from all of the worlds major oceans, and ranges from the Oligocene to Holocene.

Family BULIMINIDAE Jones, 1875

Genus *Bulimina* d'Orbigny, 1826

Bulimina buchiana d'Orbigny, 1846

Plate 17, fig. 3

Bulimina buchiana d'Orbigny, 1846, p. 186, pl. 11, figs 15-18.

Occurrence: 7 specimens from 4 samples.

Description: Test triserial, about twice as long as wide, circular in section, initial end rounded, chambers inflated, increasing in size slowly, stacked above one another in successive whorls, about four clear whorls in adult, sutures depressed, well defined, wall smooth, finely perforate, about six ridges run vertically down each chamber, widest at the margin, aperture an elongate opening surrounded by a lip and containing a tooth.

Remarks: This species was originally described form the Middle Miocene of the Vienna Basin.

Bulimina elongata d'Orbigny, 1846

Plate 17, figs 4,5, Plate 49, figs 4,5

Bulimina elongata d'Orbigny, 1846, p. 187, pl. 11, figs 19-20.

Bulimina elongata d'Orbigny. – Papp & Schmid, 1985, p. 233, pl. 63, figs 5-9.

Occurrence: 1069 specimens from 33 samples.

Description: Test triserial, elongate, slender, often slightly curved, initial end acute, chambers inflated, increasing in size slowly, sutures depressed, well defined, wall smooth, finely perforate, aperture a rounded opening surrounded by a lip and containing a tooth.

Remarks: Described originally from the Tertiary of the Vienna Basin, this species is similar in form to *Stainforthia concava* (Höglund) described from the Holocene of Sweden and also recorded from the Pliocene of the Gulf of Mexico.

Bulimina falconensis Renz, 1948

Plate 17, figs 7,8

Bulimina falconensis Renz, 1948, pl. 6, fig. 15.

Bulimina falconensis Renz. – Blow, 1959, p. 149-150. – Bolli et al., 1994, pl. 78, fig. 32.

Occurrence: 125 specimens from 21 samples.

Description: Test triserial becoming biserial, elongate, three to four times as long as wide, circular in section, initial end rounded, chambers inflated, increasing in size slowly, sutures depressed, well defined, wall smooth, finely perforate, twelve to eighteen costae running length of test, some discontinuous, often plate-like,

depressed at sutures, aperture an elongate opening surrounded by a lip and containing a tooth.

Remarks: This species was originally described from Venezuela. Differs from *B. sculptilis* Cushman in having more numerous costae.

Bulimina macilenta Cushman & Parker, 1939

Plate 17, fig. 9

Bulimina denticulata Cushman & Parker, 1936, p. 42, pl. 7, figs 7-8

Bulimina macilenta, new name, Cushman & Parker, 1939, p. 93. – Cushman & Stainforth, 1945, p. 40, pl. 6, fig. 4. – Beckman, 1953, p. 366, pl. 21, fig. 10. – Wood et al., 1985.

Occurrence: 14 specimens from 8 samples.

Description: Test triserial, length only slightly greater than width, widest near the apertural end, initial end acute, last whorl encompasses approximately half the test, chambers inflated, increasing in size rapidly, slightly undercut, about four whorls, sutures depressed, obscured in early portion, wall smooth, finely perforate, margins of chambers cut into channels with short spines projecting downwards, aperture a rounded opening surrounded by a lip and containing a tooth.

Remarks: Originally described as a junior synonym of *B. truncana* Gümbel var. *denticulata* Protescu from the Eocene of California. This species was recorded ranging into the Early Miocene in Trinidad (Bolli et al., 1994).

Bulimina marginata d'Orbigny, 1826

Plate 17, figs 10,11

Bulimina marginata d'Orbigny, 1826, p. 296.

Bulimina marginata d'Orbigny. – Kohl, 1985, pl. 20, fig. 3.

Occurrence: 233 specimens from 18 samples.

Description: Test triserial, length one and a half width, widest near the apertural end, initial end acute, chambers inflated, increasing in size rapidly, slightly undercut, margins occupied by numerous downward projecting spines, about four whorls, sutures depressed, wall smooth, finely perforate, aperture a rounded opening surrounded by a lip and containing a tooth.

Remarks: Originally described from the Adriatic, this species has been recorded in many localities in the Miocene to Holocene of the Gulf of Mexico and Atlantic.

Bulimina mexicana Cushman, 1940

Plate 17, fig. 12

Bulimina inflata Seguenza var. *mexicana* Cushman, 1922, p. 95, pl. 21, fig. 2.

Bulimina striata d'Orbigny var. *mexicana* Cushman. – in Cushman & Parker, 1940, p. 16, pl. 3, fig. 9.

Bulimina striata mexicana Cushman. – Kohl, 1985, pl. 20, fig. 4. – Robertson, 1998, p. 147, pl. 56, fig. 7.

Bulimina mexicana Cushman. – Van Morkhoven et al., 1986, p. 61, pl. 19, figs 1-4.

Occurrence: 6 specimens from 3 samples.

Description: Test triserial, about twice as long as wide, circular in section, initial end acute, chambers inflated, increasing in size slowly, about five clear whorls in adult, sutures depressed, well defined, wall smooth, finely perforate, numerous costae run the length of test, ending in narrow spines at eh margin, aperture an elongate to rounded opening surrounded by a lip and containing a tooth.

Remarks: This species is recorded from many localities in the Miocene and Pliocene of the

Atlantic, Gulf of Mexico, Caribbean, and Pacific. It has also been recorded from West Africa.

Bulimina sculptilis Cushman, 1923

Plate 17, fig. 6

Bulimina sculptilis Cushman, 1923, p. 23, pl. 3, fig. 19. – Bolli et al., 1994, p. 236, pl. 53, figs 34-35, p. 302, pl. 81, fig. 12.

Occurrence: 6 specimens from 6 samples.

Description: Test triserial, elongate, three times as long as wide, circular in section, initial end rounded, chambers inflated, increasing in size slowly, sutures depressed, well defined, wall smooth, finely perforate, eight to ten costae running length of test, often plate-like, sometimes depressed at sutures, aperture an elongate opening surrounded by a lip and containing a tooth.

Remarks: Occurs in the Late Eocene to Oligocene in Trinidad.

***Bulimina* spp.**

Plate 17, fig. 13

Occurrence: 5 specimens from 3 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test triserial, elongate, chambers inflated, sutures depressed.

Family BULIMINELLIDAE Hofka,

Genus *Praeglobobulimina* Hofker, 1951

Praeglobobulimina ovata (d'Orbigny, 1846)

Plate 17, fig. 14

Bulimina ovata d'Orbigny, 1846, p. 185, pl. 11, figs 13-14.

Bulimina ovata d'Orbigny. – Brady, 1884, p. 400, pl. 50, fig. 13.

Praeglobobulimina ovata (d'Orbigny). – Jones, 1994, pl. 50, fig. 13.

Occurrence: 5 specimens from 3 samples.

Description: Test triserial, elongate, two and a half times as long as wide, circular in section, initial end tapered, chambers inflated, strongly overlapping earlier ones, increasing in size rapidly, sutures depressed, strongly oblique, wall smooth, finely perforate, aperture an elongate loop-like opening surrounded by a lip and containing a tooth.

Praeglobobulimina socialis (Bornemann, 1855)

Plate 18, fig. 1

Bulimina Socialis Bornemann, 1855, p. 342, pl. 16, fig. 10.

Praeglobobulimina Socialis (Bornemann). – Robertson, 1998, p. 149, pl. 57, fig. 2.

Occurrence: 13 specimens from 5 samples.

Description: Test triserial, ovoid, one and a half times as long as wide, circular in section, initial end rounded, chambers inflated, strongly overlapping earlier ones, increasing in size rapidly, sutures flush with surface becoming slightly depressed, wall smooth, finely perforate, aperture an elongate loop-like opening surrounded by a lip and containing a tooth.

Remarks: Originally described from the Oligocene of Germany, has also been recorded from the Miocene of Jamaica. This species differs from *P. ovata* (d'Orbigny) in its broader outline and less oblique sutures.

Genus *Buliminella* Cushman, 1911

***Buliminella* sp.1**

Plate 18, fig. 2

Occurrence: 7 specimens from 3 samples.

Description: Test elongate, trochospiral, few complete whorls, chambers numerous, elongate, broad, low, inflated, sutures depressed, slightly curved, perpendicular to the direction of growth and nearly parallel to the long axis, surface smooth, perforate, aperture a terminal loop.

Subfamily UVIGERININAE Haeckel, 1894

Genus *Uvigerina* d'Orbigny, 1826

Uvigerina* aff. *carapitana Hedberg, 1937

Plate 18, figs 3,4,9

Uvigerina carapitana Hedberg, 1937, p. 677, pl. 91, fig. 20.

Uvigerina carapitana Hedberg. – Cushman & Renz, 1947, p. 29, pl. 6, fig. 15. – Boersma, 1984, p. 28, pl. 1, figs 1-5. – Bolli et al., 1994, p. 238, pl. 54, figs 3-4, p. 296, pl. 78, fig. 33.

Occurrence: 648 specimens from 36 samples.

Description: Test triserial, elongate in adult, length three times the width, widest near the centre, initial end acute, chambers inflated, increasing in size rapidly in early stage, then increasing slowly, about eight whorls in total, sutures depressed, wall smooth, finely perforate, aperture a rounded opening at the end of a raised neck.

Remarks: This species usually occurs as the juvenile form in the studied samples. Differs slightly in morphology from *U. carapitana* by lacking feint striae, and occasionally possessing more than three chambers. Was originally described from the mid Tertiary of Venezuela.

Uvigerina hispida Schwager, 1866

Plate 18, figs 6-8

Uvigerina hispida Schwager, 1866, p. 249, pl. 7, fig. 95.

Uvigerina hispida Schwager. – Van Morkhoven et al., 1986, p. 62, pl. 20, figs 1-4. – Boersma, 1984, p. 74, pl. 1, figs 1-5.

Occurrence: 43 specimens from 16 samples.

Description: Test triserial, elongate in adult, length twice the width, widest near the apertural end, initial end rounded, chambers inflated, increasing in size rapidly, about three whorls in total, sutures depressed, wall finely perforate, hispid, covered in long narrow spines, aperture a rounded opening at the end of a raised neck.

Remarks: *Uvigerina hispida* is a cosmopolitan species recorded from the Miocene to Pleistocene of all major oceans.

Uvigerina macrocarinata Papp & Turnovsky, 1953

Plate 18, figs 10-12

Uvigerina macrocarinata Papp & Turnovsky, 1953, p. 123.

Uvigerina macrocarinata Papp & Turnovsky. – Boersma, 1984, p. 99, pl. 1, figs 1-5.

Occurrence: 105 specimens from 19 samples.

Description: Test triserial, circular in section, large in size, elongate, length twice the width, widest in mid to upper part of test, initial end rounded, chambers inflated, increasing in size rapidly, about three whorls in total, sutures depressed, wall finely perforate, covered in six to eight costae per chamber, sometimes platy, rarely running full length of test, aperture a rounded opening at the end of a raised neck, set into a slight depression.

Remarks: Originally described from the Early Miocene of Europe, this is a widespread Tethyan form ranging up to the Pliocene.

Uvigerina mantaensis Cushman & Edwards, 1938

Plate 19, figs 1,2

Uvigerina mantaensis Cushman & Edwards, 1938, p. 84, pl. 14, fig. 8.

Uvigerina mantaensis Cushman & Edwards. – Cushman & Stainforth, 1945, p. 47, pl. 7, fig. 17. – Bermúdez, 1949, p. 207, pl. 13, fig. 48. – Boersma, 1984, p. 103, pl. 1, figs 1-6. – Kohl, 1985, pl. 24, fig. 4.

Occurrence: 194 specimens from 18 samples.

Description: Test triserial, elongate, length twice the width, widest in mid part of test, initial end rounded, chambers very inflated, increasing in size rapidly, about three whorls in total, sutures depressed, wall finely perforate, covered in densely spaced fine hisps, , aperture a rounded opening at the end of a raised neck, set into a slight depression.

Remarks: Originally described from the Tertiary of Ecuador, this species ranges from the Oligocene to Miocene in the Caribbean, and the Miocene of West Africa (Boersma, 1984).

Uvigerina* aff. *mediterranea Hofker, 1932

Plate 19, fig. 3

Uvigerina mediterranea Hofker, 1932, p. 118, fig. 32

Uvigerina mediterranea Hofker. – Van der Zwaan et al., 1986, pl. 5, figs 1-7.

Occurrence: 4 specimens from 3 samples.

Description: Test triserial, circular in section, large in size, length about twice the width, widest in mid to upper part of test, initial end rounded, chambers much inflated, increasing in size rapidly, about two to three whorls in total, sutures depressed, wall finely perforate, ornamented with costae usually restricted to each chamber, ridge-like, either running parallel to long axis, or in irregular plane, aperture a rounded opening at the end of a raised neck, set into a slight depression, containing lip.

Remarks: Common from the Mediterranean and Atlantic regions, true *U. mediterranea* posses slightly longer tests and is restricted from Pliocene to Recent. It is possible that these few specimens are caved from stratigraphically younger sections in the well.

Uvigerina proboscidea Schwager, 1866

Plate 19, fig. 4

Uvigerina proboscidea Schwager, 1866, p. 250, pl. 7, fig. 96.

Uvigerina proboscidea Schwager. – Boersma, 1984, p. 131, pl. 1, figs 1-5. – Van Morkhoven et al., 1986, p. 29, pl. 6, figs 1-4.

Occurrence: 5 specimens from 1 sample.

Description: Test triserial becoming biserial, elongate in adult, length twice the width, widest near the central part of test, initial end rounded, chambers inflated especially in the middle of test, increasing in size rapidly, sutures depressed, wall finely perforate, ornamented with numerous short hisps, aperture a rounded opening at the end of a raised neck.

Remarks: Boersma (1984) records this taxon as a cosmopolitan form from the Early Miocene to Recent but however, migrated to depths greater than 1000 metres only by the Late Miocene.

Uvigerina spinulosa Hadley, 1934

Plate 18, fig. 5

Uvigerina spinulosa Hadley, 1934, p. 18, pl. 2, fig. 17.

Uvigerina spinulosa Hadley. – Boersma, 1984, p. 163, pl. 1, figs 1-6. – Van Morkhoven et al., 1986, p. 218, pl. 74, figs 1-3.

Occurrence: 5 specimens from 4 sample.

Description: Test triserial, elongate in adult, length two to three times the width, widest near the centre, initial end rounded, chambers inflated, increasing in size rapidly, about five whorls in total, sutures much depressed, wall smooth, coarsely perforate, coarse striae run vertically down each chamber, sometimes bifurcating, sometimes forming slight spines at margin, aperture a rounded opening at the end of a raised neck.

Remarks: Originally described from Cuba, this species is recorded from Oligocene to Pliocene localities around the Pacific and Atlantic Oceans.

Family FURSENKOINIDAE Loeblich & Tappan, 1961

Genus *Fursenkoina* Loeblich & Tappan, 1961

Fursenkoina bramlettei (Galloway & Morrey, 1929)

Plate 19, fig. 5

Virgulina bramlettei Galloway & Morrey, 1929, p. 37, pl. 5, fig. 14.

Virgulina bramlettei Galloway & Morrey. – Cushman, 1937b, p. 19, pl. 3, figs 6-9.

Fursenkoina bramlettei (Galloway & Morrey). – Kohl, 1985, pl. 29, fig. 1.

Occurrence: 3 specimens from 2 samples.

Description: Test biserial, elongate, narrow, width about five times the length, slightly compressed, ovate in section, chambers slightly inflated, about five pairs in total, sutures depressed, wall smooth, aperture terminal narrow opening.

Remarks: Originally described from the Tertiary of Ecuador, this species has been recorded also from California and Mexico where it possesses a slight twist in the initial portion.. Ranges from Oligocene to Holocene.

Family STILOSTOMELLIDAE Finlay, 1947

Genus *Neugeborina* Popescu, 1998

Neugeborina longiscata (d'Orbigny, 1846)

Plate 19, fig. 6

Nodosaria longiscata d'Orbigny, 1846, p. 32, pl. 1, figs 10-12.

Nodosaria longiscata d'Orbigny. – Cushman & Stainforth, 1945, p. 24, pl. 3, figs 19-21. – Bermúdez, 1949, p. 145, pl. 9, fig. 57. – Kohl, 1985, pl. 6, fig. 3. – Papp & Schmid, 1985, p. 113, pl. 3, figs 1-5.

Neugeborina longiscata d'Orbigny. – Cicha et al.,1998, p. 195, pl. 21, fig. 12.

Occurrence: 2 specimens from 2 samples.

Description: Test much elongated, chambers cylindrical, not increasing in width as added, sutures slightly depressed, wall smooth.

Remarks: Transferred by Cicha et al. (1998), this species is cosmopolitan from the Oligocene to Miocene.

Genus *Siphonodosaria* Silvestri, 1924

Siphonodosaria* aff. *abyssorum (Brady, 1881)

Plate 19, fig. 7

Nodosaria abyssorum Brady, 1881, pl. 63, figs 8-9.

Siphonodosaria abyssorum (Brady). – Loeblich & Tappan, 1987, pl. 858, figs 5-7.

Stilostomella abyssorum (Brady). – Jones, 1994, pl. 63, figs 8-9, suppl. pl. 2, figs 8-9.

Occurrence: 14 specimens from 7 samples.

Description: Test uniserial, elongate, rectilinear to arcuate, chambers globular, increasing gradually in

size as added, sutures slightly depressed, striae sometimes present at sutures, wall smooth, aperture terminal.

Remarks: Originally described from the Recent of the South Pacific.

Genus *Stilostomella* Guppy, 1894

Stilostomella adolphina (d'Orbigny, 1846)

Plate 19, fig. 8

Dentalina adolphina d'Orbigny, 1846, p. 51, pl. 2, figs 18-20.

Stilostomella adolphina (d'Orbigny). – Papp & Schmid, 1985, p. 135, pl. 14, figs 8-11.

Occurrence: 22 specimens from 12 samples.

Description: Test uniserial, elongate, rectilinear, chambers globular, increasing gradually in size as added, occasionally decreasing as added, sutures depressed, wall smooth, spines present at margin in the form of downward pointing projections, up to two rows per chamber, aperture terminal.

Remarks: Originally described from the Tertiary of the Vienna Basin.

Stilostomella subspinosa (Cushman, 1943)

Plate 19, figs 9-11

Ellipsonodosaria subspinosa Cushman, 1943, p. 92, pl. 16, figs 6-7.

Ellipsonodosaria subspinosa Cushman. – Cushman & Stainforth, 1945, p. 56, pl. 9, figs 9-10.

Stilostomella subspinosa (Cushman). – Bolli et al, 1994, p. 256, pl. 63, fig. 30.

Occurrence: 29 specimens from 14 samples.

Description: Test uniserial, elongate, rectilinear, chambers globular, increasing gradually in size as added, overlapping previous chambers by varying degrees, sutures slightly depressed, wall spinose, either covering the entirety of the chamber, or on the lower half in the early chambers, aperture terminal.

Remarks: This species was first described from the Middle Miocene of Trinidad.

Subfamily BAGGINA Cushman, 1926

Genus *Valvulineria* Cushman, 1926

Valvulineria pseudotumeyensis Futyan, 1976

Plate 19, fig. 12-15, Plate 49, fig. 6

Valvulineria pseudotumeyensis Futyan, 1976, p. 531, pl. 83, figs 4-6.

Occurrence: 453 specimens from 22 samples.

Description: Test low trochospiral, periphery broadly rounded to slightly elongate, biconvex in side view, chambers distinct, increasing in size steadily as added, nine to ten in the final whorl, sutures distinct, curved on spiral side, straighter on umbilical side, limbate, raised on spiral side, sometimes slightly raised on umbilical side, wall smooth, perforate, aperture an extraumbilical slit covered by a large umbilical flap, and bordered by a fine lip at the base of the apertural face.

Remarks: This species was originally described from the Early Eocene of southern Jordan, and appears there in chalk overlying the Paleocene / Eocene boundary in high abundance but in only four samples. Our specimens differ only in having slightly smaller and less raised sutures on the spiral side. This species also closely resembles *Ecuadorota bristowi* Whittaker 1988, described from the Early Miocene of Ecuador. It is possible that our specimens are in fact members of this species, or that all three are of the same species.

Family DISCORBIDAE Ehrenberg, 1838

Genus *Neoeponides* Reiss, 1960

Neoeponides campester (Palmer & Bermúdez, 1941)

Plate 20, figs 1,2

Eponides byramensis (Cushman) var. *cubensis* Palmer & Bermúdez, 1936, p. 302, pl. 20, figs 4-6.

Eponides byramensis (Cushman) var. *campester* Palmer & Bermúdez, *in* Palmer, 1941, *nom. nov.*, p. 192.

Gyroidinoides byramensis (Cushman) var. *campester* (Palmer & Bermúdez). – Renz, 1948, p. 139, pl. 8, fig. 15, pl. 9, fig. 1.

Neoeponides campester (Palmer & Bermúdez). – Van Morkhoven et al., 1986, p. 153, pl. 50, fig. 1. – Robertson, 1998, p. 181, pl. 73, fig. 4.

Occurrence: 27 specimens from 6 samples.

Description: Test low trochospiral, periphery acute and limbate, biconvex in side view, umbilical side slightly more elevated, chambers narrow on spiral side, increasing in size only gradually as added, seven to ten in the final whorl, sutures oblique on spiral side, slightly curved on umbilical, limbate, wall smooth, coarsely perforate, aperture a long slit stretching from the umbilicus to the margin along the base of the apertural face, bordered by a fine lip at the base of the apertural face.

Remarks: This species was first described from the Oligocene of Cuba, and has since been reported from Venezuela, Trinidad, Jamaica, Pacific, Atlantic and Europe from Oligocene to Middle Miocene sediments.

Family SPHAEROIDINIDAE Cushman, 1927

Genus *Sphaeroidina* d'Orbigny, 1826

Sphaeroidina bulloides d'Orbigny, 1826

Plate 20, fig. 3

Sphaeroidina bulloides d'Orbigny, 1826, p. 267, Modeles no. 65.

Sphaeroidina bulloides d'Orbigny. – Cushman & Todd, 1945, p. 65, pl. 11, fig. 9. – LeRoy & Levinson, 1974, p. 8, pl. 5, fig. 2. – Kohl, 1984, pl. 14, fig. 6. – Van Morkhoven et al., 1986, p. 81, pl. 24, figs 1-2.

Occurrence: 30 specimens from 11 samples.

Description: Test rounded globular in outline, coiling trochospiral becoming irregular streptospiral, chambers inflated, three visible in the outer whorl, strongly embracing, sutures distinct and depressed, wall smooth, imperforate, aperture at the base of the final chamber, crescent shaped, surrounded by a slight lip.

Remarks: This species has been reported from Oligocene to Pliocene sediments in the Atlantic, Gulf of Mexico, California, Pacific, Europe and the Mediterranean.

Family PARRELLOIDINIDAE Hofka, 1956

Genus *Cibicidoides* Thalmann, 1939

Cibicidoides crebbsi (Hedberg, 1937)

Plate 20, figs 4,5

Eponides crebbsi Hedberg, 1937, pl. 92, fig. 1.

Eponides crebbsi Hedberg. – Cushman & Renz, 1947, pl. 7, fig. 19. – Renz, 1948, pl. 12, fig. 26. – Bolli et al., 1994, p. 240, pl. 55, figs 16-17, p. 298, pl. 79, fig. 8.

Cibicidoides crebbsi (Hedberg). – Díaz de Gamero, 1985, pl. 7, fig. 12. – Van Morkhoven et al., 1986, p. 140, pl. 45A, figs 1-2, p. 142, pl. 45B, fig. 1.

Occurrence: 715 specimens from 24 samples.

Description: Test low trochospiral, periphery acute and limbate, biconvex to planoconvex in side view, spiral side sometimes flat, chambers narrow on spiral side, increasing in size only gradually as added, ten to thirteen in the final whorl, sutures curved on spiral side, curved sigmoidal on

umbilical, meeting in centre to form an umbo, wall smooth, coarsely perforate, aperture a basal slit stretching from the umbilicus to the margin along the base of the apertural face, bordered by a lip at the base of the apertural face.

Remarks: Originally described from the Middle Tertiary of Venzuela, this species had been recorded in Late Oligocene to Middle Miocene bathyal deposits from the Gulf of Mexico and West Africa.

Cibicidoides dohmi Bermúdez, 1949

Plate 21, figs 1,3

Cibicidoides dohmi Bermúdez, 1949, p. 297, pl. 24, figs 25-27.

Cibicidoides dohmi Bermúdez. – Van Morkhoven, et al., 1986, p. 197, pl. 66, figs 1-2.

Occurrence: 9 specimens from 7 samples.

Description: Test low trochospiral, rounded in outline, stout in side view, flattened to slightly convex spiral side, strongly convex dorsal side, umbo on spiral side, margin sub rounded, chambers numerous, fourteen to fifteen in final whorl, sutures not distinct, curved on both sides, wall smooth, very coarsely perforate on both sides, aperture a slit at the base of the last chamber, extending partly towards the umbilicus.

Remarks: This species was originally described from the Tertiary of the Dominican Republic. It has been observed also in the Atlantic and Pacific Oceans throughout the Late Oligocene to Middle Miocnene.

Cibicidoides grimsdalei (Nuttall, 1930)

Plate 21, fig. 2

Cibicides grimsdalei Nuttall, 1930, p. 291, pl. 25, figs 7-8, 11.

Cibicides grimsdalei (Nuttall). – Van Morkhoven et al., 1986, p. 248, pl. 83A, figs 1-3, p. 250, pl. 83B, figs 1-7.

Occurrence: 10 specimens from 6 samples.

Description: Test low trochospiral, rounded in outline, stout in side view, almost as thick as wide, flattened to slightly convex spiral side, strongly convex dorsal side, margin rounded, chambers increase in size gradually, sutures depressed, curved on both sides, wall smooth, very coarsely perforate on both sides, irregular pitting on spiral side, aperture small and arched, located on the margin and extending into the spiral side, bordered by a prominent lip.

Remarks: Originally described from the Eocene of Mexico, this species has been recorded ranging up to the Early Miocene in the Pacific Ocean.

Cibicidoides guazumalensis (Bermúdez, 1949)

Plate 21, fig. 4

Cibicides subtenuissimus (Nuttall) var. *guazumalensis* Bermúdez, 1949, p. 306, pl. 25, figs 43-45.

Cibicidoides guazumalensis (Bermúdez). – Van Morkhoven et al., 1986, p. 144, pl. 46, figs1-2.

Occurrence: 3 specimens from 3 samples.

Description: Test low trochospiral, rounded to oval in outline, planoconvex, spiral side flat, umbilical side conical, periphery acute, chambers numerous, nine to ten in final whorl, sutures slightly depressed on umbilical side, strongly sigmoidal, flush on spiral side, curved, aperture a small low slit at the base of the apertural face, bordered by a lip.

Remarks: Miocene species from localities in Europe and the Atlantic.

Cibicidoides havanensis (Cushman & Bermúdez, 1937)

Plate 21, fig. 5, Plate 22, fig. 1

Cibicides havanensis Cushman & Bermúdez, 1937, p. 28, pl. 3, figs 1-3.

Cibicidoides havanensis (Cushman & Bermúdez). – Van Morkhoven et al., 1986, p. 191, pl. 64A, figs 1-4, p. 192, pl. 64B, figs 1-2. – Robertson, 1998, p. 195, pl. 80, fig. 1. – Kuhnt et al., 2002, p. 143, pl. 8, figs 1-11.

Occurrence: 36 specimens from 19 samples.

Description: Test low trochospiral, round in outline, biconvex, half as thick as wide, margin acute, chambers increase in size only gradually, numerous, sutures straight and oblique on umbilical side, largely obscured on spiral, wall smooth, coarsely perforate on both sides, aperture small and arched, located on the margin of final chamber.

Remarks: Originally described from the Eocene of Cuba, this species is cosmopolitan and has been recorded in deposits as young as Middle Miocene.

Cibicidoides mundulus (Brady, Parker & Jones, 1888)

Plate 22, figs 2,3

Truncatulina mundula Brady, Parker & Jones, 1888, p. 228, pl. 45, fig. 25.

Cibicidoides mundulus (Brady, Parker & Jones). Loeblich & Tappan, 1955, p. 25, pl. 4, fig. 4. – Van Morkhoven et al., 1986, p. 66, pl. 21, fig. 1.

Occurrence: 145 specimens from 40 samples.

Description: Test low trochospiral, round in outline, biconvex, margin acute, chambers increase in size only gradually, ten to twelve in final whorl, sutures curved, flush with surface, wall smooth, coarsely perforate, aperture small and arched, located on the margin of final chamber.

Remarks: A long ranging species, *C. mundulus* is cosmopolitan throughout from Oligocene to Pleistocene.

Cibicidoides pachyderma (Rzehak, 1886)

Plate 22, fig. 4

Truncatulina pachyderma Rzehak, 1886, p. 87, pl. 1, fig. 5.

Cibicidoides pachyderma (Rzehak). – Van Morkhoven et al., 1986, p. 71, pl. 22, fig. 1.

Occurrence: 82 specimens from 21 samples.

Description: Test low trochospiral, round in outline, biconvex, margin acute with keel, chambers increase in size only gradually, numerous, ten to twelve in final whorl, sutures slightly curved and oblique on umbilical side, strongly curved on spiral side, wall smooth, coarsely perforate on both sides, aperture small and arched, located on the margin of final chamber.

Remarks: This species has been reported in Oligocene to Pleistocene sediments and has a cosmopolitan distribution.

***Cibicidoides* spp.**

Occurrence: 372 specimens from 21 samples.

Description: Included in this group are all fragmentary and unassigned forms, including internal moulds, displaying the following characteristics: test trochospiral, rounded in outline, chambers increase in size only gradually, wall smooth.

Subfamily PSEUDOPARRELLINAE Voloshinova, 1952

Genus *Megastomella* Faulkner, de Klasz & Rérat, 1963

Megastomella africana Faulkner, de Klasz & Rérat, 1963

Plate 22, fig. 6

Megastomella africana Faulkner, de Klasz & Rérat, 1963, p. 19.

Megastomella africana Faulkner, de Klasz & Rérat. – Loeblich & Tappan, 1987, p. 574, pl. 627, fig. 1.

Occurrence: 6 specimens from 5 samples.

Description: Test low trochospiral, oval in outline, flattened biconvex, margin acute, chambers increase in size rapidly, eight to nine in final whorl, sutures slightly curved, wall smooth, perforate, aperture a long vertical slit extending up the face of the relatively high apertural face, from the umbilicus to the margin.

Remarks: This species has been recorded from the Lower to Upper Miocene of Gabon, West Africa, and California.

Family PLANULINIDAE Bermúdez, 1952

Genus *Planulina* d'Orbigny, 1826

Planulina renzi Cushman & Stainforth, 1945

Plate 23, figs 1-3

Planulina renzi Cushman & Stainforth, 1945, p. 72, pl. 15, fig. 1.

Planulina renzi Cushman & Stainforth. – Van Morkhoven et al., 1986, p. 134, pl. 43A, figs 1-5, p. 136, pl. 43B, figs 1-2.

Occurrence: 10 specimens from 8 samples.

Description: Test large, low trochospiral, oval in outline, very flattened biconvex, margin acute, strong keel, sixteen to eighteen chambers in final whorl, increasing in size slowly, sutures curved, limbate, raised greatly and ornamented with pustules, wall smooth, highly perforate, aperture a narrow basal opening bordered by a lip.

Remarks: A truly cosmopolitan species ranging from the Oligocene to Miocene from bathyal environments.

Subfamily NONIONINAE Schultz, 1854

Genus *Nonion* de Montford, 1808

***Nonion* sp. 1**

Plate 22, fig. 5

Occurrence: 49 specimens from 18 samples.

Description: Test planispiral, oval in outline, coiling involute, slightly compressed, periphery broadly rounded, chambers inflated, increasing in size rapidly as added, about seven in the final whorl, sutures intensely depressed at umbilicus, becoming less so towards to periphery, curved, wall smooth, aperture a slit at the base of the apertural face.

Subfamily PULLENIINAE Schwager, 1877

Genus *Melonis* de Montford, 1808

Melonis pompilioides (Fichtel & Moll, 1798)

Plate 23, fig. 4

Nautilus pompilioides Fichtel & Moll, 1798, p. 31, pl. 2, figs a-c.

Melonis pompilioides (Fichtel & Moll). – Rögl & Hansen, 1984, p. 30, pl. 2, figs 1-2. – Van Morkhoven et al., 1986, p. 73, pl. 23A, figs 1-2, p. 75, pl. 23B, figs 1-2, p. 77, pl. 23C, fig. 1, p. 73, pl. 23A, figs 1-2, p. 78, pl. 23D, fig. 1, p. 79, pl. 23E, fig. 1.

Occurrence: 31 specimens from 17 samples.

Description: Test small, planispiral, involute, round in outline, almost as broad as wide, margin round, nine to eleven chambers in final whorl, increasing in size slowly, sutures straight, flush with surface, wall smooth, coarsely perforate,

aperture wide narrow interiomarginal basal slit bordered by a lip.

Remarks: Recorded globally from deposits spanning the Oligocene to Pleistocene.

Genus *Pullenia* Parker & Jones,1862

Pullenia bulloides (d'Orbigny, 1846)

Plate 23, fig. 5

Nonionina bulloides d'Orbigny, 1826, p. 293.

Nonionina bulloides d'Orbigny, 1846, p. 107, pl. 5, figs 9-10.

Pullenia bulloides (d'Orbigny). – Galloway & Morrey, 1929, p. 43, pl. 6, fig. 16. Kohl, 1985, pl. 32, fig. 5. – Papp & Schmid, 1985, p. 175, pl. 34, figs 6-9.

Occurrence: 6 specimens from 5 samples.

Description: Test small, planispiral, involute, almost spherical, four to five chambers in final whorl, globular, increasing in size slowly, sutures straight, flush with surface, wall smooth, very finely perforate, aperture wide narrow interiomarginal basal slit bordered by a lip.

Remarks: This species, originally described from the Tertiary of the Vienna Basin, is cosmopolitan and has been recorded from sediments of Oligocene to Recent in age.

Family ORIDORSALIDAE Loeblich & Tappan, 1984

Genus *Oridorsalis* Andersen, 1961

Oridorsalis umbonatus (Reuss, 1851)

Plate 23, fig. 6, Plate 24, figs 1,2, Plate 49, fig. 8

Rotalia umbonata Reuss, 1851, p. 75, pl. 5, fig. 35.

Rotalia ecuadorensis Galloway & Morrey, 1929, p. 26, pl. 3, fig. 13.

Eponides umbonatus (Reuss) var. *ecuadorensis* (Galloway & Morrey). – Hedberg, 1937, p. 679, pl. 91, fig. 22.

Oridorsalis umbonatus (Reuss). – Saunders et al., 1984, p. 408, pl. 4, fig. 10. – Bolli et al., 1994, p. 247, pl. 58, figs 10-13.

Occurrence: 265 specimens from 23 samples.

Description: Test trochospiral, round in outline, biconvex, about half as thick as wide, umbilical side more convex than spiral, margin acute, sometimes with developed fine keel, chambers increase in size gradually, six in final whorl, sutures radial, straight to slightly curved on spiral side, straight to becoming strongly curved on the umbilical side near the umbo, sutures flush to test, wall smooth, aperture a small arch, located in the bottom centre of the apertural face, surrounded by a lip.

Remarks: The species originally described by Reuss differs from some of our specimens in having a developed keel and straight umbilical sutures. These characteristics are present in some of the specimens analysed in this study, and we see a complete gradation between these forms and ones containing strongly curved sutures on the umbilical side and an acute periphery but no keel. We regard these features as variable within the species, and use wall structure, number of chambers, a high umbilical side and aperture as defining characteristics. Under this description fall the specimens described and pictured by Galloway & Morrey as *Rotalia ecuadorensis*.

Subfamily GYROIDINOIDINAE Saidova, 1981

Genus *Gyroidinoides* Brotzen, 1942

Gyroidinoides altiformis (Stewart & Stewart, 1930)

Plate 24, fig. 3

Gyroidina soldanii (d'Orbigny) var. *altiformis* Stewart & Stewart, 1930, p. 67, pl. 9, fig. 2.

Gyroidinoides altiformis (Stewart & Stewart). – Beckman, 1953, p. 381, pl. 23, fig. 22. – Becker & Dusenbury, 1958, p. 38, pl. 5, fig. 1. – Kohl, 1985, p. 95, pl. 34, fig. 3.

Occurrence: 45 specimens from 15 samples.

Description: Test large, trochospiral, round in outline, biconvex, spiral side sometimes flat, umbilical side highly convex, margin sub acute, chambers increase in size gradually, ten in the final whorl, sutures limbate, straight and oblique on spiral side, radial on the umbilical side, slightly depressed, wall smooth, aperture a long slit located at the base of the apertural face stretching from the margin to the umbilicus, with a small flap extending into the umbilicus.

Remarks: Originally described form the Pliocene of California, this species has also been recorded from Oligocene to Holocene sediments of Central America and the Gulf of Mexico.

Gyroidinoides altispira (Cushman & Stainforth, 1945)

Plate 24, fig. 4

Gyroidina altispira Cushman & Stainforth, 1945, p. 61, pl. 11, fig. 1.

Gyroidina altispira Cushman & Stainforth. – Bermúdez, 1949, pl. 252, pl. 17, figs 58-60.

Gyroidinoides altispira (Cushman & Stainforth). – Robertson, 1998, p. 244, pl. 98, fig. 2.

Occurrence: 1 specimen from 1 sample.

Description: Test trochospiral, round in outline, biconvex, spiral side highly convex, margin sub acute, chambers increase in size gradually, ten in the final whorl, sutures limbate, straight and oblique on spiral side, radial on the umbilical side, slightly depressed, wall smooth, aperture a long slit located at the base of the apertural face stretching from the margin to the umbilicus, with a small flap extending into the umbilicus.

Remarks: Has been reported from the Oligocene to Miocene of Trinidad, the Dominican Republic and Jamaica.

Gyroidinoides soldanii (d'Orbigny, 1826)

Plate 25, figs 1,2

Gyroidina soldanii d'Orbigny, 1826, p. 278 (fide Ellis & Messina, 1940)

Rotalina soldanii d'Orbigny, 1846, p. 155, pl. 8, figs 10-12.

Gyroidina soldanii d'Orbigny. – Cushman, 1929, pl. 14, fig. 7. – Papp & Schmid, 1985, p. 60, pl. 50, figs 4-9.

Gyroidinoides cf. *soldanii* (d'Orbigny). – Renz, 1948, p.140, pl. 8, fig. 14. – Bolli et al., 1994, p. 378, pl. 80, fig. 4.

Gyroidinoides soldanii (d'Orbigny). – Cimerman & Langer, 1991, p. 75, pl. 85, figs 5-6.

Occurrence: 81 specimens from 20 samples.

Description: Test trochospiral, round in outline, biconvex, spiral side sometimes flat, umbilical side highly convex, margin sub acute, chambers inflated, increasing in size gradually, eight to ten in the final whorl, sutures depressed, radial and straight on spiral and umbilical sides, wall smooth, aperture a slit located at the base of the apertural face stretching from the margin to the umbilicus, with a small flap extending into the umbilicus.

Remarks: Originally described from the Recent of Italy, this species has also been reported from the Tertiary of the Vienna Basin, Venezuela and California. The presence of an umbilical flap in the

studied specimens places the species in the genus *Gyroidinoides*.

Subfamily GRAVELLINAE Hofker, 1956

Genus *Gyroidina* d'Orbigny, 1826

Gyroidina orbicularis d'Orbigny, 1826

Plate 25, figs 3,4

Gyroidina orbicularis d'Orbigny, 1826, p. 278, Modeles no. 13 (a plaster-caste model was used to depict this species).

Gyroidina orbicularis d'Orbigny. – Phleger & Parker, 1951, p. 22, pl. 11, figs 11-12. – LeRoy & Levinson, 1974, p. 14, pl. 7, figs 14-16. – Kohl, 1985, p. 93, pl. 33, figs 1-2.

Occurrence: 20 specimens from 11 samples.

Description: Test trochospiral, round in outline, biconvex, spiral side sometimes flat, umbilical side convex, margin sub acute, chambers increase in size gradually, eight to ten in the final whorl, sutures straight and oblique on spiral side, radial on the umbilical side, slightly depressed, wall smooth, aperture a slit located at the base of the apertural face stretching from the margin to the umbilicus, with a narrow lip.

Remarks: This species has been recorded from the Holocene of the Atlantic, Pacific, Adriatic and Gulf of Mexico, and from the Neogene of Papua New Guinea.

Gyroidina umbonata (Silvestri, 1898)

Plate 26, fig. 1

Rotalia soldanii d'Orbigny var. *umbonata* Silvestri, 1898, p. 239, pl. 6, fig. 14.

Gyroidina umbonata (Silvestri). – Kohl, 1985, p. 94, pl. 33, fig. 3.

Occurrence: 1 specimen from 1 sample.

Description: Test trochospiral, round in outline, spiral side flat, umbilical side convex, margin sub rounded, chambers inflated, increasing in size gradually, seven in the final whorl, sutures straight, depressed, wall smooth, aperture a slit located at the base of the apertural face stretching from the margin to the umbilicus, with a narrow lip.

Remarks: Originally described from the Pliocene of Italy, this species is also recorded from the Miocene of Venezuela and Pliocene of Mexico.

Genus *Hanzawaia* Asano, 1944

Hanzawaia mantaensis (Galloway & Morrey, 1929)

Plate 26, figs 3,4

Anomalina mantaensis Galloway & Morrey, 1929, p. 28, pl. 4, fig. 5.

Cibicides mantaensis (Galloway & Morrey). – Hedberg, 1937, p. 683, pl. 92, fig. 12. – Cushman & Renz, 1947, p. 44, pl. 8, fig. 7.

Hanzawaia mantaensis (Galloway & Morrey). – Bolli et al., 1994, p. 379, pl. 61, figs 1-3, pl. 80, fig. 7.

Occurrence: 242 specimens from 25 samples.

Description: Test low trochospiral, oval in outline, higher than wide, spiral side flat to slightly convex, umbilical side slightly convex, margin acute, chambers increasing in size gradually, ten to thirteen in the final whorl, sutures strongly curved, strongly limbate, raised, wall smooth, perforate, aperture a slit located at the base of the apertural face, with a narrow lip.

Remarks: Originally described from the lower Tertiary of Ecuador, this species has also been recorded from Venezuela and Trinidad.

***Hanzawaia* sp. 1**

Plate 26, fig. 2

Occurrence: 16 specimens from 7 samples.

Description: Test low trochospiral, oval in outline, higher than wide, spiral and umbilical sides slightly convex, margin sub acute, chambers increasing in size gradually, nine in the final whorl, sutures curved, depressed, especially in the umbilical region, wall smooth, aperture a slit located at the base of the apertural face.

Remarks: Differs from *H. carstansi* (Cushman & Ellisor) in having depressed sutures rather than limbate, and a more rounded periphery.

Subfamily AMMONIINAE Saidova, 1981

Genus *Ammonia* Brunnich, 1772

Ammonia* cf. *parkinsoniana (d'Orbigny, 1839)

Plate 26, fig. 5

Rosalina parkinsoniana d'Orbigny, 1839, p. 99, pl. 4, figs 25-27.

Ammonia parkinsoniana (d'Orbigny). – Le Calvez, 1977, p. 92, pl. 11, figs 1-3. – Cimerman & Langer, 1991, p. 76, pl. 87, figs 7-9.

Occurrence: 1 specimen from 1 sample.

Description: Test low trochospiral, round in outline, spiral side convex, umbilical side slightly convex, margin sub acute, chambers increasing in size gradually, nine in the final whorl, sutures straight, strongly depressed on the umbilical side, with deeply incised cavities between chambers, well developed knob in umbilicus, wall smooth, perforate, aperture an interiomarginal opening at the base of the apertural face, slit-like, extending toward the umbilicus.

Remarks: Differs from true *A. parkinsoniana* by having a more rounded outline, and more convex umbilical side. This species was first described from the Recent of Cuba.

***Ammonia* sp.**

Plate 26, fig. 6

Occurrence: 6 specimens from 4 samples.

Description: Included in this group are all unassigned forms, including internal moulds, displaying the following characteristics: test trochospiral, rounded in outline, biconvex, chambers increasing in size slowly, strongly depressed sutures on the umbilical side, with deeply incised cavities between chambers, wall smooth, aperture slit-like opening at the base of the apertural face.

PLANKTONIC FORAMINIFERA

Catapsydrax unicavus Bolli, Loeblich & Tappan, 1957

Plate 27, fig. 1

Catapsydrax unicavus Bolli, Loeblich & Tappan, 1957, p. 37, pl. 7, fig. 9.

Catapsydrax unicavus Bolli, Loeblich & Tappan. – Kennett & Srinivasan, 1983, p. 26, pl. 3, figs 1-3.

Occurrence: 4 specimens from 5 samples.

Remarks: Contains three chambers in the final whorl, with a bulla attached by three sides. *G. suteri* differs in having four chambers and bulla, and an interiomarginal aperture.

Stratigraphic distribution: Late Eocene to top zone N6 (Kennett & Srinivasan, 1983).

Dentoglobigerina altispira altispira (Cushman & Jarvis, 1936)

Plate 29, fig. 3

Globigerina altispira Cushman & Jarvis, 1936, p. 5, pl. 1, fig. 13.

Dentoglobigerina altispira altispira (Cushman & Jarvis). – Kennett & Srinivasan, 1983, p. 188, pl. 46, figs 4-6.

Globoquadrina altispira altispira (Cushman & Jarvis). – Bolli & Saunders, 1985, p. 183, pl. 15, fig. 1.

Occurrence: 3 specimens from 3 samples.

Stratigraphic distribution: Late Oligocene to Early Pliocene (Kennett & Srinivasan, 1983).

Globigerina praebulloides Blow, 1959

Plate 49, fig. 7

Globigerina praebulloides Blow, 1959, p. 180, pl. 8, fig. 47, pl. 9, fig. 48.

Occurrence: Several specimens present.

Stratigraphic distribution: Late Eocene to Late Miocene (Kennett & Srinivasan, 1983).

Globigerinella obesa (Bolli, 1957)

Plate 29, fig. 4

Globorotalia obesa Bolli, 1957, p. 119, pl. 29, figs 2,3.

Globigerinella obesa (Bolli, 1957). – Kennett & Srinivasan, 1983, p. 234, pl. 59, figs 2,3.

Occurrence: 19 specimens from 11 samples.

Remarks: Four to four-and-a-half chambers in the final whorl, periphery strongly lobate.

Stratigraphic distribution: Late Oligocene to Recent.

Globigerinella praesiphonifera (Blow, 1969)

Plate 29, fig. 6

Hastigerina (H.) siphonifera praesiphonifera Blow, 1969, p. 408, pl. 54, figs 7-9.

Globigerinella praesiphonifera (Blow, 1969). – Kennett & Srinivasan, 1983, p. 238, pl. 60, figs 1-3.

Occurrence: 5 specimens from 4 samples.

Remarks: Five chambers in the final whorl, lobate periphery.

Stratigraphic distribution: Zone N4 to N13 (Kennett & Srinivasan, 1983).

Globigerinoides bisphericus Todd, 1954

Plate 27, figs 5, 8

Globigerinoides bisphericus Todd, 1954, p. 681, pl. 1, fig. 1.

Globigerinoides bisphericus Todd. – Jenkins et al., 1981, p. 265, pl. 1, fig. 1. – Bolli & Saunders, 1985, p. 199, pl. 24, fig. 8.

Occurrence: 24 specimens from 14 samples.

Remarks: Distinguished from *G. trilobus* in possessing two slit-like apertures.

Stratigraphic distribution: Base N7 to top of *P. sicana* range intra N9 (Bolli & Saunders, 1985).

Globigerinoides immaturus LeRoy, 1939

Plate 27, fig. 3

Globigerinoides sacculiferus (Brady) var. *immature* LeRoy, 1939, p. 263, pl. 3, figs 19-21.

Globigerinoides immaturus LeRoy. – Kennett & Srinivasan, 1983, p. 64, pl. 13, figs 7-9.

Occurrence: Several specimens present.

Remarks: Distinguished from *G. trilobus* in possessing a less dominant final chamber.

Stratigraphic distribution: Zone N5 to Recent (Kennett & Srinivasan, 1983).

Globigerinoides sacculifer (Brady, 1877)

Plate 27, fig. 2

Globigerina sacculifer Brady, 1877, p. 604, pl. 80, figs 11-17, pl. 81, fig. 2, pl. 82, fig. 4.

Globigerinoides sacculifer (Brady, 1877) – Kennett & Srinivasan, 1983, p. 66, pl. 14, figs 4-6.

Occurrence: 6 specimens from 5 samples.

Remarks: Several supplementary apertures on spiral side, whilst *G. altiaperturus* Bolli differs by having only one.

Stratigraphic distribution: Zone N4b to Recent (Spezzaferri, 1994).

Globigerinoides subquadratus Brönnimann, 1954

Globigerinoides subquadratus Brönnimann, 1954, p. 680, pl. 1, fig. 8.

Occurrence: 5 specimens from 4 samples.

Stratigraphic distribution: Zone N4b to N15 (Kennett & Srinivasan, 1983).

Globigerinoides trilobus (Reuss, 1850)

Plate 27, fig. 4, Plate 49, figs 11,12

Globigerina triloba Reuss, 1850, p. 374, pl. 47, fig. 11.

Globigerinoides trilobus (Reuss, 1850) – Spezzaferri, 1994, p. 37, pl. 13, fig. 1, pl. 15, fig. 6.

Occurrence: 58 specimens from 26 samples.

Remarks: Distinguished from *G. bisphericus* by possessing two high-arched apertures.

Stratigraphic distribution: Zone intra N4b to Recent (Spezzaferri, 1994).

Globoquadrina dehiscens (Chapman, Parr & Collins, 1934)

Plate 29, fig. 1

Globorotalia dehiscens Chapman, Parr & Collins, 1934, p. 569, pl. 11, fig. 36.

Globoquadrina dehiscens (Chapman, Parr & Collins, 1934). – Kennett & Srinivasan, 1983, p. 184, pl. 45, figs 7-9.

Occurrence: 4 specimens from 3 samples.

Stratigraphic distribution: Zone N4b to N18 (Kennett & Srinivasan, 1983).

Globoquadrina venezuelana (Hedberg, 1937)

Plate 29, fig. 2

Globigerina venezuelana Hedberg, 1937, p. 681, pl. 92, fig. 72.

Globoquadrina venezuelana (Hedberg, 1937). – Kennett & Srinivasan, 1983, p. 180, pl. 44, figs 5-7.

Occurrence: 2 specimens from 2 samples.

Stratigraphic distribution: Middle Eocene to Pliocene (Kennett & Srinivasan, 1983).

Globorotalia archeomenardii Bolli, 1957

Globorotalia archeomenardii Bolli, 1957, p. 119, pl. 28, fig. 11.

Globorotalia archeomenardii Bolli. – Bolli & Saunders, 1985, p. 223, pl. 32, fig. 6.

Occurrence: 1 specimen from 1 sample.

Remarks: Has a more rounded outline and less well-developed keel than *G. Praemenardii.*

Stratigraphic distribution: Zones N8 to N11, 16.26-13.87 Ma (Ogg & Lugowski, 2007).

Globorotalia peripheroronda Blow & Banner, 1966

Plate 28, fig. 3,4

Globorotalia (Turborotalia) peripheroronda Blow & Banner, 1966, p. 294, pl. 1, fig. 1.

Globorotalia (Fohsella) peripheroronda Blow & Banner. – Kennett & Srinivasan, p. 96, pl. 22, figs 1-3.

Globorotalia peripheroronda Blow & Banner. – Spezzaferri, 1994, p. 58, pl. 25, fig. 6.

Occurrence: 80 specimens from 26 samples.

Remarks: Both umbilical and spiral sides show curved sutures, periphery subrounded.

Stratigraphic distribution: Zones N4a to N10 (Spezzaferri, 1994).

Globorotalia praemenardii Cushman & Stainforth, 1945

Plate 28, fig. 6

Globorotalia praemenardii Cushman & Stainforth, 1945, p. 70, pl. 13, fig. 14.

Globorotalia praemenardii Cushman & Stainforth. – Bolli & Saunders, 1985, p. 223, pl. 32, fig. 7.

Occurrence: 1 specimen from 1 sample.

Remarks: Differs from *G. archeomenardii* in having a less developed keel and less rounded outline.

Stratigraphic distribution: Zones N9 to N14, base at 14.38 Ma (Ogg & Lugowski, 2007).

Globorotalia praescitula Blow, 1959

Globorotalia scitula (Brady) subsp. *praescitula* Blow, 1959, p. 221, pl. 19, fig. 128

Globorotalia praescitula Blow. – Kennett & Srinivasan, 1983, p. 108, pl. 25, figs 4-6. – Bolli & Saunders, 1985, p. 217, pl. 31, fig. 6.

Occurrence: 10 specimens from 7 samples.

Stratigraphic distribution: Zone intra N5 (20.28 to 18.75 Ma) to N10. Miller et al. (1991) record the FAD of this species at the base of Chron C5En (18.52 Ma) at Site 608, northern North Atlantic. Berggren et al. (1995) use the FAD in the Mediterranean as a marker for the base of zone Mt3 (18.5 Ma). However, Morgans et al. (2002) record the species at the base Chron C5Er in New Zealand, and postulate a FAD somewhere between C6n to base C5Er (20.28 to 18.75 Ma). They also note that the population sizes are very small and regard the species as easy to overlook. Spezzaferri (1994) records the FAD of uppermost Zone N5 for this species as regionally synchronous in the Pacific and Indian oceans, but occurring lower in this zone at Site 526 in the South Atlantic. We therefore suspect that the FAD in this location may be significantly older than the widely used age of 18.5 Ma.

Globorotaloides hexagonus (Natland, 1938)

Plate 29, fig. 5

Globigerina hexagona Natland, 1938, p. 149, pl. 7, fig. 1.

Globorotaloides hexagona (Natland, 1938). – Kennett & Srinivasan, 1983, p. 216, pl. 54, figs 3-5.

Occurrence: 1 specimen from 1 sample.

Stratigraphic distribution: Zones N7 to Recent (Kennett & Srinivasan, 1983).

Globorotaloides permicrus (Blow & Banner, 1962)

Globorotalia (Turborotalia) permicrus Blow & Banner, 1962, p. 120, pl. 12, figs N-P.

Globorotaloides permicrus (Blow & Banner). – Spezzaferri, 1994, p. 46, pl. 35, fig. 2.

Occurrence: 1 specimen from 1 sample.

Stratigraphic distribution: Spezzaferri (1994) reported this species as ranging from the early Oligocene to early Miocene.

Globorotaloides suteri Bolli, 1957

Plate 49, fig. 9

Globorotaloides suteri Bolli, 1957, p. 117, pl. 27, figs 9-13.

Globorotaloides suteri Bolli. – Kennett & Srinivasan, 1983, p. 214, pl. 53, figs 1, 3-5.

Occurrence: 18 specimens from 14 samples.

Stratigraphic distribution: Middle Eocene to within N8 (Kennett & Srinivasan, 1983).

Orbulina bilobata (d'Orbigny, 1846)

Plate 28, fig. 1

Globigerina bilobata d'Orbigny, 1846, p. 164, pl. 9, figs 11-14.

Orbulina bilobata (d'Orbigny). – Kennett & Srinivasan, 1983, p. 88, pl. 20, figs 7-9.

Occurrence: 1 specimen from 1 sample.

Stratigraphic distribution: Kennett & Srinivasan (1983) recorded this species ranging from the base of N9 (14.74 Ma) to Recent.

Orbulina universa d'Orbigny, 1839

Plate 28, fig. 2

Orbulina universa d'Orbigny, 1839, p. 3, pl. 1, fig. 1.

Orbulina universa d'Orbigny. – Kennett & Srinivasan, 1983, p. 86, pl. 20, figs 4-6.

Occurrence: 1 specimen from 1 sample.

Stratigraphic distribution: Zone N9 (14.74 Ma) to Recent (Ogg & Lugowski, 2007). Also given the same range as *O. bilobata* by Kennett & Srinivasan (1983).

Paragloborotalia bella Jenkins, 1967

Paragloborotalia bella Jenkins, 1967, p. 1069, fig. 3, nos. 1-6.

Paragloborotalia bella Jenkins. – Kennett & Srinivasan, 1983, p. 174, pl. 43, figs 1-3.

Occurrence: 11 specimens from 5 samples.

Stratigraphic distribution: Zone M2 to M5a (Kennett & Srinivasan, 1983).

Paragloborotalia mayeri (Cushman & Ellisor, 1939)

Plate 28, fig. 5

Globorotalia mayeri Cushman & Ellisor, 1939, p. 11, pl. 2, fig. 4.

Globorotalia mayeri Cushman & Ellisor. – Kennett & Srinivasan, 1983, p. 174, pl. 43, figs 4-6. – Bolli & Saunders, 1985, p. 203, pl. 26, figs 31-43.

Occurrence: 12 specimens from 6 samples.

Remarks: Specimens with five to six chambers in the final whorl, periphery rounded, sutures slightly curved.

Stratigraphic distribution: Zones N3 to N14 (Bolli & Saunders, 1985.

***Paragloborotalia opima nana / continuosa* transitional form**

Globorotalia opima nana Bolli, 1957, p. 118, pl. 28, fig. 3.

Globorotalia continuosa Blow, 1959, p. 218, pl. 19, fig. 125.

Occurrence: 15 specimens from 6 samples.

Remarks: Specimens transitional from *P. opima nana* to *P. continuosa* have been recorded by Bolli & Saunders (1985) to range from zone P22 to top N6.

Paragloborotalia semivera (Hornibrook, 1961)

Globigerina semivera Hornibrook, 1961, p. 149, pl. 23, figs 455-457.

Paragloborotalia semivera (Hornibrook). – Kennett & Srinivasan, 1983, p. 172, pl. 42, figs 3-4. – Spezzaferri, 1994, p. 55, pl. 20, fig. 6, pl. 22, fig. 1.

Occurrence: 1 specimen from 1 sample.

Stratigraphic distribution: From late Oligocene to intra zone M5b (Kennett & Srinivasan, 1983).

Praeorbulina glomerosa glomerosa Blow, 1956

Plate 27, fig. 7, Plate 49, fig. 10

Praeorbulina glomerosa glomerosa Blow, 1956, p. 65, text-figs 2.3-4.

Occurrence: 2 specimens from 2 samples.

Remarks: Almost spherical in outline, with numerous apertures around the base of the final chamber. This is the species *P. glomerosa* s.str. of Berggren et al. (1995).

Stratigraphic distribution: Base zone M5b to top M5b, 16.27-14.78 Ma (Ogg & Lugowski, 2007). Oldest occurrence defines the base of zone M5b (Berggren et al., 1995).

Praeorbulina sicana (de Stefani, 1952)

Plate 27, fig. 6

Globigerinoides conglobatus (Brady). – Cushman & Stainforth, 1945, 68, pl. 13, fig. 6.

Globigerinoides sicana de Stefani, 1952, p. 9, not re-illustrated.

Praeorbulina sicana (de Stefani). – Jenkins et al., 1981, p. 264, pl. 1, fig. 2.

Occurrence: 7 specimens from 7 samples.

Remarks: Possesses four slit-like apertures, with 30-40% of test enveloped by final chamber.

Stratigraphic distribution: Base zone M5a to intra M6, 16.97-14.53 Ma (Ogg & Lugowski, 2007).

14.1 Oligocene

The following taxa are listed according to the Kaminski (2004) classification of agglutinated foraminifera. Species identifications have been based in large part on the taxonomic works of Kaminski and Geroch (1993), Jones (1994) and Kaminski and Gradstein (2005).

Family RHABDAMMINIDAE Brady, 1884
Subfamily RHABDAMMININAE Brady, 1884
Genus *Rhabdammina* M. Sars in Carpenter, 1869

Rhabdammina linearis Brady, 1879
Plate 30, fig. 1

Rhabdammina linearis Brady, 1879, p. 37, pl. 3, figs 10-11.
Rhabdammina linearis Brady. –Kaminski & Gradstein, 2005, p. 124, pl. 7, figs 1a-8.
Occurrence. 6 specimens from 3 samples.

***Rhabdammina* spp.**
Plate 30, figs 2a-10

Occurrence. 792 specimens from 56 samples.
Description. We include all tubular fragments with thick wall, so that they generally form a circular or elliptical cross-section. Test size small to large, grain size fine to coarse, occasionally branching.
Remarks. We distinguish at least six different forms of *Rhabdammina* from the well, which may prove to be different species. We have listed them all under the same name for the purpose of this study, as the fragmentary pieces are not sufficient to identify species. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Subfamily BATHYSIPHONINAE Avnimelech, 1952
Genus *Bathysiphon* Sars, 1872

***Bathysiphon* spp.**
Plate 30, figs 11-13

Occurrence. 92 specimens from 27 samples.
Description. All tubular fragments with thick wall, straight and unbranching. Small to medium size. Generally smooth wall and annular constrictions.
Remarks. We distinguish at least four different forms of *Bathysiphon* from the well, which may prove to be different species. Their fragmentary nature does not allow us to identify species.

Subfamily BATHYSIPHONINAE Avnimelech, 1952
Genus *Nothia* Pflaumann, 1964

Nothia* aff. *excelsa (Grzybowski, 1898)
Plate 30, figs 14-16

Dendrophrya excelsa Grzybowski, 1898, p. 272, pl. 10, figs 2-4.
Nothia excelsa (Grzybowski, 1898). –Geroch & Kaminski, 1992, p. 255, pl. 1, figs 1-4, pl. 2, figs 1-11.
Occurrence. 248 specimens from 32 samples.

Nothia latissima (Grzybowski, 1898)
Plate 30, fig. 17, Plate 31, fig. 1

Dendrophrya latissima Grzybowski, 1898, p. 273, pl. 10, fig. 8.

Nothia latissima (Grzybowski, 1898). –Kaminski & Geroch, 1993, p. 245, pl. 1, figs. 1a-c, 14a,b.
Nothia latissima (Grzybowski). –Kaminski & Gradstein, 2005, p. 113, pl. 3, figs 1-4b.
Occurrence. 311 specimens from 25 samples.

Nothia robusta (Grzybowski, 1898)
Plate 31, figs 2,3

Dendrophrya robusta Grzybowski, 1898, p. 273, pl. 10, fig. 7.
Nothia robusta (Grzybowski, 1898). –Geroch & Kaminski, 1992, pl. 1, figs. 1-4, pl. 2, figs. 1-11.
Nothia robusta (Grzybowski). –Kaminski & Gradstein, 2005, p. 116, pl. 4, figs 1-8.
Occurrence. 2407 specimens from 57 samples.
Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Nothia* spp.**
Plate 31, fig. 4

Occurrence. 114 specimens from 33 samples.
Description. We include all tubular fragments with a thin and therefore much flattened wall. Grain size fine to coarse, finish usually rough. Specimens small to large.
Remarks. We have distinguished at least three differing forms of *Nothia* from the well, which may prove to be different species. We list them all under the same name owing to their fragmentary nature. Some specimens show a highly-silicified wall and may be reworked from the Eocene.
Family RHIZAMMINIDAE Brady, 1879
Genus *Rhizammina* Brady, 1879

***Rhizammina* spp.**
Plate 31, figs 5-7

Occurrence. 504 specimens from 44 samples.
Description. We include all tubular fragments exhibiting a very thin and delicate wall with irregular outline. Grain size medium to coarse. Wall shows a rough finish, very small to small size, occasionally branching.
Remarks. We have distinguished at least 5 different forms of *Rhizammina* from the well, which may prove to be different species. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus *Placentammina* Thalmann, 1947

Placentammina placenta (Grzybowski, 1898)
Plate 31, fig. 8

Reophax placenta Grzybowski, 1898, p. 276-277, pl. 10, figs 9-10.
Saccammina placenta (Grzybowski). –Kaminski & Geroch, 1993, p. 249, pl. 2, figs 5-7.
Placentammina placenta (Grzybowski). –Kaminski & Gradstein, 2005, p. 139, pl. 11, figs 1-6.
Occurrence. 12 specimens from 9 samples.

Genus *Saccammina* Carpenter, 1869

Saccammina* cf. *sphaerica Sars, 1872
Plate 31, figs 9,10

Saccammina sphaerica Sars, 1872, p. 250.
Saccammina sphaerica Sars. –Brady, 1884, p. 253, pl. 18, figs 11-15.
Occurrence. 72 specimens from 28 samples.
Remarks. In this group we include single chambered forms with medium test size, small apertural neck, thin to medium wall thickness, and a medium to coarse grain size. Some specimens

show a highly-silicified wall and may be reworked from the Eocene.

***Saccammina* sp. 1**

Plate 31, fig. 11

Occurrence. 44 specimens from 17 samples.

Description. Single chamber, medium to large in size, thick wall, medium grain size with a fine finish. Aperture a small neck.

Remarks. Differs from *S. sphaerica* by having a much thicker wall.

***Saccammina* sp. 2**

Occurrence. 2 specimens from 2 samples.

Description. Single chamber, very large in size, thick wall, medium grain size with a fine finish. Aperture a small neck.

Remarks. Similar to *Saccammina* sp. 1, but with a much larger size.

***Saccammina* sp. 3**

Plate 31, fig. 12

Occurrence. 8 specimens from 6 samples.

Description. Single chamber, very large in size, thick wall, coarse grain size. Aperture a small neck.

***Saccammina* spp.**

Occurrence. 38.5 specimens from 21 samples.

Description. We include all single chambered fragments, small to large in size, fine to medium grained.

Remarks. Generally indistinguishable fragments. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Family PSAMMOSPHAERIDAE Haeckel, 1894

Subfamily PSAMMOSPHAERINAE Haeckel, 1894

Genus *Psammosphaera* Schulze, 1875

Psammosphaera* cf. *fusca Schultze, 1875

Plate 31, figs 14a,b

Psammosphaera fusca Schultze, 1875, p. 113, pl. 2, figs 8a-f.

Occurrence. 67 specimens from 20 samples.

Remarks. This group includes single chambered forms with small to medium test size, thin to medium wall thickness, and a medium to coarse grain size. Aperture is merely a depression or gap between sand grains.

***Psammosphaera* sp. 1**

Plate 31, fig. 13

Occurrence. 24 specimens from 10 samples.

Description. Single chamber, small to medium in size, wall thick, grain size medium. Finish sometimes smooth. Aperture is a depression or gap between sand grains.

***Psammosphaera* sp. 2**

Occurrence. 1 specimen.

Description. Single chamber, very large test size, thin to medium wall thickness, and a medium to coarse grain size. Aperture is merely a depression or gap between sand grains.

Remarks. Similar to *Psammosphaera fusca* Schultze but with a much larger test size.

***Psammosphaera* spp.**

Occurrence. 9 specimens from 6 samples.

Description. Single chambered, small to large, coarse grained.

Remarks. Generally indistinguishable fragments.

Family HIPPOCREPINIDAE Rhumbler, 1895

Subfamily HIPPOCREPININAE Rhumbler, 1895

Genus *Jaculella* Brady, 1879

***Jaculella* sp. 1**

Plate 31, fig. 15

Occurrence. 2 specimens from 2 samples.

Description. Test tubular, tapering, conical. Wall medium thickness, coarse grained, roughly finished.

Remarks. Both specimens are fragmentary.

Family HYPERAMMINIDAE Eimer & Fickert, 1899

Subfamily HYPERAMMININAE Eimer & Fickert, 1899

Genus *Hyperammina* Brady, 1878

Hyperammina elongata Brady, 1878

Plate 31, fig. 16

Hyperammina elongata Brady, 1878, p. 433, pl. 1, figs 16,18,19.

Occurrence. 1 specimen.

***Hyperammina* spp.**

Plate 32, figs 1,2

Occurrence. 9 specimens from 9 samples.

Description. Forms with a large proloculus followed by an undivided tube, fine to medium grained, small to large in size.

Remarks. Specimens generally fragmentary.

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMODISCINAE Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

Ammodiscus cretaceus (Reuss, 1845)

Plate 32, fig. 3a

Operculina cretacea Reuss, 1845, p. 35, pl. 13, figs 64-65.

Ammodiscus cretacea (Reuss). –Cushman, 1934, p. 45.

Ammodiscus cretaceus (Reuss). –Kaminski & Gradstein, 2005, p. 147, pl. 14, figs 1a-10.

Occurrence. 42.5 specimens from 20 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

Ammodiscus latus Grzybowski, 1898

Plate 32, figs 4-6

Ammodiscus latus Grzybowski, 1898, p. 282, pl. 10, figs 27-28.

Ammodiscus latus Grzybowski. –Kaminski & Gradstein, 2005, p. 152, pl. 16a, figs 1-8, p. 153, pl. 16b, figs 1-6.

Occurrence. 187 specimens from 51 samples.

Ammodiscus* aff. *peruvianus (Berry, 1928)

Plate 32, fig. 9

Ammodiscus peruvianus Berry, 1928, p. 342, pl. 27.

Ammodiscus peruvianus Berry. –Kaminski & Gradstein, 2005, p. 159, pl. 18, figs 1a-6.

Occurrence. 2 specimens from 2 samples.

Ammodiscus tenuissimus Grzybowski, 1898

Plate 32, fig. 7

Ammodiscus tenuissimus Grzybowski, 1898, p. 282, pl. 10, fig. 35.

Ammodiscus tenuissimus Grzybowski. –Kaminski & Gradstein, 2005, p. 163, pl. 20, figs 1a-7.

Occurrence. 1 specimen.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Ammodiscus* sp. 1**

Plate 32, fig. 8

Occurrence. 12 specimens from 7 samples.

Description. Test small, planispiral, strongly compressed along the long axis so that the test forms an elongated shape. Chamber increasing only gradually in size, aperture terminal. Wall fine grained with a smooth finish.

***Ammodiscus* sp. 2**

Plate 32, figs 10,11

Occurrence. 4 specimens from 3 samples.

Description. Test medium to large in size, planispiral sometimes becoming uncoiled, slightly elongated. Chamber increasing rapidly in size, rounded, inflated, 'sausage-like', thick. Wall thick, medium grain size with a smooth finish.

***Ammodiscus* spp.**

Plate 32, figs 12,13

Occurrence. 32.5 specimens from 20 samples.

Description. We include all planispiral forms with one chamber coiling around an initial proloculus.

Remarks. Usually unidentified due to poor preservation.

Subfamily TOLYPAMMININAE Cushman, 1928

Genus *Ammolagena* Eimer & Fickert, 1899

Ammolagena clavata (Jones & Parker, 1860)

Plate 31, fig. 15, Plate 32, fig. 3b

Trochammina irregularis (d'Orbigny) var. *clavata* Jones & Parker, 1860, p. 304.

Ammolagena clavata (Jones & Parker). –Kaminski & Gradstein, 2005, p. 165, pl. 21, figs 1-6.

Occurrence. 12 specimens from 9 samples.

Subfamily USBEKISTANIINAE Vyalov, 1977

Genus *Glomospira* Rzehak, 1885

Glomospira charoides (Jones & Parker, 1860)

Plate 32, fig. 14

Trochammina squamata Jones & Parker var. *charoides* Jones & Parker, 1860, p. 304.

Glomospira charoides (Jones & Parker). –Berggren & Kaminski, 1990, pl. 1, fig. 2.

Glomospira charoides (Jones & Parker). – Kaminski & Gradstein, 2005, p. 173, pl. 22, figs 1-16.

Occurrence. 45 specimens from 24 samples.

Glomospira glomerata (Grzybowski, 1898)

Plate 32, fig. 15

Ammodiscus glomeratus Grzybowski, 1898, p. 285, pl. 11, fig. 4.

"Glomospira" glomerata (Grzybowski). – Kaminski & Gradstein, 2005, p. 179, pl. 24, figs 1-6.

Occurrence. 4 specimens from 3 samples.

Glomospira gordialis (Jones & Parker, 1860)

Plate 33, fig. 1

Trochammina squamata Jones & Parker var. *gordialis* Jones & Parker, 1860, p. 304.

Glomospira gordialis (Jones & Parker). –Berggren & Kaminski, 1990, pl. 1, fig. 1.

Glomospira glomerata (Jones & Parker). – Kaminski & Gradstein, 2005, p. 184, pl. 25, figs 1-8.

Occurrence. 13 specimens from 9 samples.

Glomospira irregularis (Grzybowski, 1898)

Plate 33, fig. 2

Ammodiscus irregularis Grzybowski, 1898, p. 285, pl. 11, figs 2, 3.

Glomospira irregularis (Grzybowski). –Kaminski & Geroch, 1993, p. 256, pl. 6, fig. 6-8b.

Glomospira irregularis (Grzybowski). –Kaminski & Gradstein, 2005, p. 187, pl. 26, figs 1a-7.

Occurrence. 27 specimens from 13 samples.

Glomospira* aff. *irregularis (Grzybowski, 1898)

Plate 33, figs 3,4

Occurrence. 6 specimens from 3 samples.

Remarks. Similar to *G. irregularis*, but with a larger tube, coarser wall, and less convolutions. The specimens are all fragmentary however.

***Glomospira* sp. 1**

Plate 33, figs 5,6

Occurrence. 5 specimens from 3 samples.

Description. Test small, initially glomospirally enrolled, becoming planispiral. Test flattened. Single chamber increasing in size only gradually. Wall thin, fine grained, with a smooth finish.

***Glomospira* sp. 2**

Plate 33, fig. 7

Occurrence. 3 specimens from 3 samples.

Description. Test medium to large in size, single chambered. Initial coiling irregular to glomospiral, later planispiral. Chamber large, thin, slightly flattened, and increasing only gradually in size. Wall coarse with a rough finish.

***Glomospira* spp.**

Occurrence. 29 specimens from 13 samples.

Remarks. All fragmentary and as yet unidentifiable specimens with single coiled chamber.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Caudammina* Montanaro-Gallitelli, 1955

Caudammina* aff. *ovuloides (Grzybowski, 1901)

Plate 33, fig. 8

Reophax ovuloides Grzybowski, 1901, p. 223, pl. 8, fig. 3.

Caudammina ovuloides (Grzybowski). –Kaminski & Gradstein, 2005, p. 240, pl. 42, figs 1-7.

Occurrence. 2 specimens from 2 samples.

Description. Test flask shaped, originally multichambered, tubular aperture at one end on a protruding neck, similar aperture at opposite end. Wall medium to thick, grain size medium.

Remarks. Very similar to *Caudammina ovuloides*, known from the Cretaceous and early Paleogene only. Specimens show a highly-silicified wall and may be reworked.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Hormosinella* Shchedrina, 1969

Hormosinella carpenteri (Brady, 1884)

Plate 33, fig. 9

Trochammina (Hormosina) carpenteri Brady, 1881, p. 51 [no figure given].

Hormosina carpenteri Brady, 1884, pl. 31, figs 16-22 [earliest figure].

Occurrence. 1 specimen.

Genus *Reophanus* Saidova, 1970

Reophanus berggreni Gradstein & Kaminski, 1997

Plate 33, fig. 10

Reophanus berggreni Gradstein & Kaminski, 1997, p. 220, textfig. 4, fig. 5, 1-7b.

Reophanus berggreni Gradstein & Kaminski. – Kaminski & Gradstein, 2005, p. 265, pl. 50, figs 1-7.

Occurrence. 3 specimens from 2 samples.

Family HORMOSINELLIDAE Rauser & Reitlinger, 1986

Genus *Subreophax* Saidova, 1975

Subreophax pseudoscalaris (Samuel, 1977)

Plate 33, fig. 11

Reophax pseudoscalaria Samuel, 1977, p. 36, pl. 3, figs 14a,b.

Subreophax pseudoscalaris (Samuel). –Kaminski & Gradstein, 2005, p. 282, pl. 56, figs 1-6.

Occurrence. 4 specimens from 2 samples.

Subreophax scalaris (Grzybowski, 1896)

Plate 33, figs 12,13

Reophax guttifera Brady var. *scalaria* Grzybowski, 1896, p. 277, pl. 8, fig. 26.

Subreophax scalaris (Grzybowski). –Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 2, figs 16-17.

Reophax scalaris (Grzybowski). –Kaminski & Gradstein, 2005, p. 279, pl. 55, figs 1-7.

Occurrence. 11 specimens from 8 samples.

Family ASCHEMOCELLIDAE Vyalov, 1966

Genus *Aschemocella* Vyalov, 1966

Aschemocella grandis (Grzybowski, 1898)

Plate 33, figs 14,15

Reophax grandis Grzybowski, 1898, p. 277, pl. 10, figs 13-15.

Aschemocella grandis (Grzybowski). –Kaminski & Geroch, 1993, p. 249, pl. 2, figs 8-10.

Aschemocella grandis (Grzybowski). –Kaminski & Gradstein, 2005, p. 229, pl. 39, figs 1-8b.

Occurrence. 15 specimens from 8 samples.

***Aschemocella* spp.**

Plate 33, fig. 16

Occurrence. 4 specimens from 4 samples.

Description. We include all unidentified fragments of large multichambered forms, where chambers do not increase in size with growth.

Genus *Kalamopsis* de Folin, 1883

***Kalamopsis* spp.**

Plate 33, fig. 17

Occurrence. 19 specimens from 9 samples.

Description. All forms with a rectilinear series of tubular chambers, thick wall, generally smooth finish. Forms unbranching, medium in size.

Family REOPHACIDAE Cushman, 1927

Genus *Hormosinelloides* Saidova, 1975

Hormosinelloides guttifer (Brady, 1884)

Plate 34, fig. 1

Reophax guttifer Brady, 1881, p. 49 [no figure given].

Reophax guttifer Brady, 1884, pl. 31, figs 10-15 [earliest figure].

Hormosinelloides guttiferus (Brady). –Zheng & Fu, 2001, p. 278, pl. 16, figs 16-22 [n.comb.].

Occurrence. 5 specimens from 3 samples.

Genus *Reophax* de Montfort, 1808

Reophax duplex Grzybowski, 1896

Plate 34, fig. 2

Reophax duplex Grzybowski, 1896, p.276, pl. 8, figs 23-24.

Reophax duplex Grzybowski. –Kaminski & Gradstein, 2005, p. 268, pl. 51, figs 1-9.

Occurrence. 5 specimens from 4 samples.

Reophax pilulifer (Brady, 1884)

Plate 34, figs 3,4

Reophax pilulifer Brady, 1884, p. 292, pl. 30, figs 18-20.

Reophax pilulifer Brady. –Kaminski & Gradstein, 2005, p. 273, pl. 53, figs 1a-9.

Occurrence. 51.5 specimens from 24 samples.

Reophax pyrifer Rhumbler, 1905

Plate 34, figs 5,6

Reophax pyrifer Rhumbler, 1905, p. 103, text-fig. 4.

Occurrence. 4 specimens from 3 samples.

***Reophax* sp. 1**

Plate 34, figs 7,8

Occurrence. 4 specimens from 3 samples.

Description. Test small, uniserial, consisting of up to three rectilinear chambers increasing in size rapidly. Aperture terminal. Wall thin. Test collapsed. Grainsize coarse, texture of the test rough.

***Reophax* sp. 2**

Plate 34, fig. 9

Occurrence. 5 specimens from 2 samples.

Description. Test large in size, consisting of at least two globular chambers attached in a rectilinear series increasing only slightly in size. Wall very thick and coarse. Chambers overlapping about 20% of previous chambers

***Reophax* spp.**

Plate 34, fig. 10

Occurrence. 29 specimens from 14 samples.

Remarks. We include all unidentified fragmentary specimens of multichambered unilocular foraminifera.

Family HORMOSINIDAE Haeckel, 1894

Subfamily HORMOSININAE Haeckel, 1894

Genus *Hormosina* Brady, 1879

Hormosina glabra Cushman & Stainforth, 1945

Plate 34, fig. 11

Hormosina glabra Cushman & Stainforth, 1945, p. 14, pl. 1, fig. 9.

Occurrence. 4 specimens from 1 sample.

Hormosina globulifera Brady, 1879

Plate 34, fig. 12

Hormosina globulifera Brady, 1879, p. 60, pl. 4, figs 4-5.

Occurrence. 70 specimens from 24 samples.

***Hormosina* spp.**

Occurrence. 1 specimen from 1 sample.

Remarks. Fragmentary specimen of *H. globulifera* with unidentified aperture.

Genus *Pseudonodosinella* Saidova, 1970

Pseudonodosinella elongata (Grzybowski, 1898)

Plate 34, fig. 13

Reophax elongata Grzybowski, 1898, p. 279, pl. 10, figs 19-20.

Pseudonodosinella elongata (Grzybowski). – Kaminski & Geroch, 1993, p. 295, pl. 3, figs 1-5.

Occurrence. 2 specimens from 1 sample.

Family KUNKLERINIDAE Rauser & Reitlinger, 1986

Genus *Scherochorella* Loeblich & Tappan, 1984

Subclass Textulariia Mikhalevich 1980

Order Lituolida Lankester 1885

Suborder Hormosinina Mikhalevich 1980

Superfamily Hormosinacea Haeckel 1894

Family Kunklerinidae Rauser and Reitlinger 1986

Genus *Scherochorella* Loeblich and Tappan 1984

Scherochorella congoensis Kender, Kaminski and Jones

Plate 34, figs 14-16, Plate 46, figs 1-6

Scherochorella congoensis Kender, Kaminski & Jones, 2006, p. 465, pl. 1, figs 1-6.

Material: 1213 specimens from 31 samples, Upper Oligocene.

Type locality: Congo Fan, offshore Angola, Block 31.

Type level: Cuttings sample collected at 4,040 meters below rotary table. Oligocene black shales.

Type specimens: Holotype (BMNH PF 67318) and paratypes (BMNH PF 67319) are deposited in the micropalaeontological collections of the Natural History Museum, London.

Derivation of name: After the Congo Fan, the location of its discovery.

Description: Test free (800μm in length, 150μm in width), uniserial, consisting a rectilinear series of 9-10 chambers increasing in size slowly from an initial, small proloculus. Successive chambers overlap previous ones by approximately 30%. Sutures depressed and straight. Specimens are invariably flattened in various planes. Wall thin, composed of a single layer of coarsely agglutinated sand grains 2-3 grains thick. Aperture a small, round, terminal opening within a slightly raised 'shoulder'. Cement siliceous, presumably organic before fossilisation.

Remarks: This species differs from *Scherochorella minuta* (Tappan) in its more coarsely agglutinated and thinner test wall. This species commonly occurs in great abundance in the studied well, typically making up >50% of the agglutinated specimens present in a sample. It is most commonly present as broken fragments.

Family LITUOTUBIDAE Loeblich & Tappan, 1984

Genus *Lituotuba* Rhumbler, 1895

Lituotuba lituiformis (Brady, 1879)

Plate 34, fig. 17, Plate 35, fig. 1

Trochammina lituiformis Brady, 1879, p. 59, pl. 5, fig. 16.

Occurrence. 14 specimens from 9 samples.

Genus *Paratrochamminoides* Soliman, 1972

Paratrochamminoides* ex gr. *challengeri (Rögl, 1995)

Plate 35, fig. 2

Trochamminoides challengeri Rogl, 1995, p. 256.

Paratrochamminoides challengeri (Rögl). – Kaminski & Kuhnt, 2004, p. 280.

Occurrence. 2 specimens from 2 samples.

Paratrochamminoides* aff. *deflexiformis (Noth, 1912)

Plate 35, figs 3,4

Trochammina deflexiformis Noth, 1912, p. 26, figs 10a-b.

Paratrochamminoides deflexiformis (Noth). – Kender, Kaminski & Cieszkowski, 2005, p. 263, fig. 11, K1-2.

Occurrence. 2 specimens from 2 samples.

Remarks. These specimens are poorly preserved, but exhibit the characteristic glomospiral coiling and bead-like chambers increasing in size slowly with 8-10 chambers in the final whorl that defines *P. deflexiformis*.

Suborder Lituolina Lankester 1885

Superfamily Lituotubacea Loeblich and Tappan 1984

Family Lituotubidae Loeblich and Tappan 1984

Genus *Paratrochamminoides* Soliman 1972

Paratrochamminoides gorayskiformis Kender, Kaminski and Jones

Plate 35, figs 5-8, Plate 46, figures 7-10

Paratrochamminoides gorayskiformis Kender, Kaminski & Jones, 2006, p. 466, pl. 1, figs 7-10.

Material: 12 specimens from 6 samples, Upper Oligocene to Lower Miocene.

Type specimens: Holotype (BMNH PF 67320) and paratypes (BMNH PF 67321) are deposited in the micropalaeontological collections of the Natural History Museum, London.

Type localty: Congo Fan, offshore Angola, Block 31.

Type level: Cuttings sample collected at 3,850 meters below rotary table. Oligocene black shales.

Derivation of name: Taken from its similar appearance to *Paratrochamminoides gorayskii* (Grzybowski).

Description: Test oval in outline (approximately 0.6mm in length). Coiling triloculine, coiled in three planes, with the long axis defined as in line with the intersection of the coiling planes. The tubular test is divided into chambers of varying length, from elongate to distinctly bead-like, approximately five in the last whorl. Wall is finely agglutinated with a fine to medium-coarse finish. Wall thin. Aperture at the open end of the tube. Cement siliceous, presumably organic before fossilisation.

Remarks: This species is similar to *Paratrochamminoides gorayskii* (Grzybowski) in its coiling mode and shape, but can be distinguished by its shorter chamber length and thinner wall.

Paratrochamminoides gorayskii (Grzybowski, 1898)

Plate 35, fig. 9

Ammodiscus gorayskii Grzybowski, 1898, p. 283, pl. 11, fig. 5.

Paratrochamminoides gorayskii (Grzybowski). – Kaminski & Geroch, 1993, 255, pl. 5, fig. 8a-d.

Paratrochamminoides gorayskii (Grzybowski). – Kaminski & Gradstein, 2005, p. 297, pl. 61, figs 1a-5.

Occurrence. 7 specimens from 4 samples.

Paratrochamminoides olszewskii (Grzybowski, 1898)

Plate 35, figs 10,11

Trochammina olszewskii Grzybowski, 1898, p. 298, pl. 11, fig. 6.

Paratrochamminoides olszewskii (Grzybowski). – Kaminski & Geroch, 1993, p. 257, pl. 7, figs 1a-2b.

Paratrochamminoides olszewskii (Grzybowski). – Kaminski & Gradstein, 2005, p. 307, pl. 64, figs 1a-7.

Occurrence. 21 specimens from 11 samples.

***Paratrochamminoides* sp. 1**

Plate 36, fig. 1

Occurrence. 2 specimens from 1 sample.

Description. Test large in size, coiling streptospiral, chambers numerous, inflated, increasing in size rapidly so that last whorl makes up a significant proportion of the test. Chambers globular, bead-like to slightly elongated. Wall thin, chambers collapsed. Wall is made up of medium sized grains, surface of the test is smooth.

***Paratrochamminoides* spp.**

Occurrence. 18 specimens from 13 samples.

Description. All specimens with a streptospirally enrolled test, numerous ovate to globular chambers, thin wall.

Remarks. Unidentified fragmentary and collapsed specimens.

Genus *Conglophragmium* Bermúdez & Rivero, 1963

Conglophragmium irregulare (White, 1928)

Plate 36, fig. 2

Trochamminoides irregularis White, 1928, p. 307, pl. 42, fig. 1.

Conglophragmium irregularis (White). –Kaminski & Gradstein, 2005, p. 286, pl. 57, figs 1-6.

Occurrence. 4 specimens from 3 samples.

Family TROCHAMMINOIDAE Haynes & Nwabufo-Ene, 1998

Genus *Trochamminoides* Cushman, 1910

Trochamminoides folius (Grzybowski, 1898)

Plate 36, fig. 3

Trochammina folium Grzybowski, 1898, p. 288, pl. 11, figs 7-9.

Trochamminoides folius (Grzybowski). –Kaminski & Geroch, 1993, p. 306, pl. 9, figs 1a-4b.

Occurrence. 1 specimen from 1 sample.

Remarks. Specimen shows a highly-silicified wall and may be reworked from the Eocene.

Trochamminoides* aff. *proteus (Karrer, 1866)

Plate 36, figs 4,5

Tochammina proteus Karrer, 1866, pl. 1, fig. 8.

Trochamminoides proteus (Karrer). –White, 1928, p. 308, pl. 42, fig. 2.

Trochamminoides proteus (Karrer). –Kaminski & Gradstein, 2005, p. 317, pl. 67, figs 1a-5b.

Occurrence. 2 specimens from 2 samples.

Description. Test large in size, initially irregularly coiled, later becoming planispiral. Chambers increase in size gradually and are numerous with about 7 in the last whorl. Chambers globular, bead-like, sutures straight. Wall is made up of medium sized grains, with a rough finish. Aperture is terminal and equatorial.

Remarks. Differs from its most similar form *T. proteus* by having fewer chambers in the last whorl, and larger chambers.

Trochamminoides subcoronatus (Grzybowski, 1896)

Plate 36, fig. 6

Trochammina subcoronata Grzybowski, 1896, p. 283 - 284, pl. 9, fig. 3a-c.

Trochamminoides subcoronatus (Grzybowski). – Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 192, pl. 4, fig. 19.

Trochamminoides subcoronatus (Grzybowski). – Kaminski & Gradstein, 2005, p. 319, pl. 67, figs 1a-6.

Occurrence. 6 specimens from 3 samples.

***Trochamminoides* spp.**

Occurrence. 7 specimens from 6 samples.

Description. Irregularly coiled becoming planispiral, numerous ovate to globular chambers, thin wall.

Remarks. Unidentified fragmentary and collapsed specimens.

Family HAPLOPHRAGMOIDIDAE Maync, 1952

Genus *Buzasina* Loeblich & Tappan, 1985

Buzasina* aff. *pacifica (Krasheninnikov, 1973)

Plate 36, fig. 7

Labrospira pacifica Krasheninnikov, 1973, p. 209, pl. 2, figs 4-5.

Buzasina pacifica (Krasheninnikov). –Kaminski & Gradstein, 2005, p. 337, pl. 73, figs 1-5.

Occurrence. 1 specimen from 1 sample.

Description. Test small, planispiral, with 3 chambers increasing in size rapidly. Last chamber strongly overlapping initial chambers and comprising more than half the test. Wall thick, finely agglutinated and smooth. Specimen shows a highly-silicified wall and may be reworked from the Eocene.

Genus *Evolutinella* Mjatliuk, 1970

Evolutinella rotulata (Brady, 1881)

Plate 38, fig 4

Haplophragmoides rotulatus, Brady, 1881, p. 50.

Occurrence. 1 specimen from 1 sample.

Remarks. Differs from *Budashevaella multicamerata* due to its bi-umbilicate form.

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides carinatus Cushman & Renz, 1941

Plate 36, figs 8,9

Haplophragmoides carinatus Cushman & Renz, 1941, p. 2, pl. 1, fig. 1.

Occurrence. 4 specimens from 3 samples.

Haplophragmoides* aff. *horridus (Grzybowski, 1901)

Plate 36, fig. 10

Haplophragmium horridum Grzybowski, 1901, p. 270, pl. 7, fig. 12.

Haplophragmoides horridus (Grzybowski). – Kaminski & Geroch, 1993, p. 318, pl. 15, figs 6-8.

Haplophragmoides horridus (Grzybowski). – Kaminski & Gradstein, 2005, p. 349, pl. 77, figs 1a-6.

Occurrence. 7 specimens from 3 samples.

Remarks. The specimens from this well differ from true *H. horridus* by having a thicker wall and larger final chamber compared to the previous ones. It also exhibits a coarse wall, straight sutures and four triangular inflated chambers.

Superfamily Lituolacea de Blainville 1827

Family Haplophragmoididae Maync 1952

Genus *Haplophragmoides* Cushman 1910

Haplophragmoides nauticus Kender, Kaminski and Jones

Plate 37, figs 5-6, Plate 47, figures 1-2

Haplophragmoides sp.1 Kender, Kaminski and Cieszkowski, 2005, p. 267, fig. 13b.

Haplophragmoides nauticus Kender, Kaminski & Jones, 2006, p. 468, pl. 2, figs 1-2.

Material: 45 specimens from 17 samples, Upper Oligocene to Lower Miocene.

Type specimens: Holotype (BMNH PF 67322) and paratypes (BMNH PF 67323) are deposited in the micropalaeontological collections of the Natural History Museum, London.

Type localty: Congo Fan, offshore Angola, Block 31.

Type level: Cuttings sample from 3,840 meters below rotary table. Oligocene black shales.

Derivation of name: After the Latin for 'nautical', after its association with the ocean.

Description: Test planispiral (up to 1mm diameter), circular in outline, with an acute periphery. Coiling is evolute with 9 chambers in the final whorl. Chambers are truncated triangular (trapezoidal) in shape, increasing rapidly in size. Sutures are straight to sigmoidal, and slightly depressed. Wall simple, thin, finely agglutinated and finely finished. Aperture is slit-like, located at the base of the final chamber. Cement siliceous, presumably organic before fossilisation.

Remarks: This species differs from its most closely related form *Haplophragmoides walteri* (Grzybowski) by having a distinctly evolute coiling mode and the trapezoidal chambers. *H. nauticus* has been found from many localities within the Polish Carpathians, and was recently illustrated as *Haplophragmoides* sp. 1 (Kender et al., 2005) from the Lower Eocene of the Magura Unit, Outer Carpathians.

Haplophragmoides walteri (Grzybowski, 1898)

Plate 37, fig. 1

Trochammina walteri Grzybowski, 1898, p. 290, pl. 11, fig. 31.

Haplophragmoides walteri (Grzybowski). – Kaminski & Geroch, 1993, p. 263, pl. 10, fig. 3a-7c.

Haplophragmoides walteri (Grzybowski). – Kaminski & Gradstein, 2005, p. 365, pl. 83, figs 1-6.

Occurrence. 39 specimens from 14 samples.

Remarks. This species is invariably compressed due its very thin wall. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Haplophragmoides* sp. 1**

Plate 37, figs 2,3

Occurrence. 8 specimens from 5 samples.

Description. Test medium to large in size, with 5-6 distinctly globular chambers in the last whorl. Umbilicus depressed, periphery rounded, sutures straight and depressed. Wall simple, composed of medium to coarse grains.

***Haplophragmoides* sp. 2**

Plate 37, fig. 7

Occurrence. 1 specimen.

Description. Test large, planispiral, evolute, with 8 chambers in the final whorl. Umbilicus significantly depressed. Periphery consists of a thick carina, sutures depressed and chambers inflated. Wall simple and very thickened.

Remarks. The thickened nature of this *Haplophragmoides* makes it resemble superficially a *Reticulophragmium*.

***Haplophragmoides* spp.**

Plate 37, fig. 3

Occurrence. 74.5 specimens from 33 samples.

Remarks. All fragmentary and unidentified forms with planispiral chambers.

Family DICAMMINIDAE Loeblich & Tappan, 1984

Genus *Glaphyrammina* Cushman, 1910

Glaphyrammina americana (Cushman, 1910)

Plate 37, fig. 4

Ammobaculites americanus Cushman, 1910, p. 117, figs 1-4.

Glaphyrammina americana (Cushman). –Loeblich & Tappan, 1987, p. 68, pl. 51, figs 7-10.

Occurrence. 2 specimens from 2 samples.

***Glaphyrammina* spp.**

Occurrence. 1 specimen.

Remarks. Similar to *G. americana* but broken and unclear.

Family SPHAERAMMINIDAE Cushman, 1933

Subfamily PRAESPHAERAMMININAE Kaminski & Mikhalevich, 2004

Genus *Praesphaerammina* Kaminski & Filipescu, 2000

***Praesphaerammina* sp. 1**

Plate 37, figs 8-10

Occurrence. 9 specimens from 6 samples.

Description. Test very large in size, planispiral, with 3 to 4 strongly overlapping chambers. Final chamber is so large it makes up the majority of the test. Wall is very thick and coarse, with a rough texture.

***Praesphaerammina* spp.**

Occurrence. 13.5 specimens from 11 samples.

Description. Test large, planispirally enrolled, involute, with about four strongly overlapping chambers per whorl, with the final embracing chamber overlapping over half the test. Wall fine, rough to smooth finish.

Remarks. Usually occurs as fragments of very large specimens.

Family LITUOLIDAE de Blainville, 1827

Subfamily AMMOMARGINULINAE Podobina, 1978

Genus *Ammomarginulina* Wiesner, 1931

***Ammomarginulina* spp.**

Plate 37, fig. 11

Occurrence. 6 specimens from 5 samples.

Description. Test elongate, strongly compressed. Planispiral in early stage, later uncoiled and rectilinear with oblique sutures. Wall agglutinated, roughly finished. Aperture terminal, rounded, at dorsal side of test.

Family LITUOLIDAE de Blainville, 1827

Genus *Discamminoides* Bronnimann, 1951

***Discamminoides* sp. 1**

Plate 38, figs 1,2, Plate 44, figs 1,2

Occurrence. 212 specimens from 38 samples.

Description. Test large, involute, planispiral becoming uniserial, flattened, with 4-5 chambers in last coil and up to 5 chambers in uniserial part. Chambers increase in size steadily. Initial coiled part either large or small depending on micro- or megalo- spheric generation. Periphery acute, sutures straight, seen as slight depression or undulation of test surface, or only visible as internal layer. Aperture a terminal slit. Wall bilamellar, internal layer thicker at peripheral part, coarse and sometimes speculated, with thin tubular alveoles. Outer layer medium to coarse grained and thin.

Family AMMOSPHAEROIDINIDAE Cushman, 1927

Subfamily AMMOSPHAEROIDININAE Cushman, 1927

Genus *Ammosphaeroidina* Cushman, 1910

Ammosphaeroidina pseudopauciloculata (Mjatliuk, 1966)

Plate 38, fig. 3

Cystamminella pseudopauciloculata Mjatliuk, 1966, p. 246, pl. 1, figs 5-7, pl. 2, fig. 6, pl. 3, fig. 3.

Ammosphaeroidina pseudopauciloculata (Mjatliuk). – Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 193, pl. 8, figs 3-5.

Occurrence. 109 specimens from 28 samples.

Description. Test size small to medium, streptospirally enrolled, chambers globular, increasing rapidly in size so that only the last 4 are visible in the final whorl. Wall fine to medium agglutinated, surface smoothly finished. Aperture a low interiomarginal arch.

***Ammosphaeroidina* spp.**

Occurrence. 76 specimens from 18 samples.

Description. Test small to large, streptospirally enrolled, chambers globular, increasing rapidly in size so that only the last 4 are visible in the final whorl. Wall finely to coarsely agglutinated, surface with a smooth to rough finish.

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973

Genus *Budashevaella* Loeblich & Tappan, 1964

Budashevaella multicamerata (Voloshinova & Budasheva, 1961)

Plate 38, figs 5,7

Circus multicamerata Voloshinova, 1961, p. 201, pl. 7, figs 6a-c, pl. 8, 1a-c.

Budashevaella multicamerata Voloshinova. – Kaminski & Gradstein, 2005, p. 388, pl. 90, figs 1a-6b.

Occurrence. 13 specimens from 6 samples.

***Budashevaella* spp.**

Occurrence. 6 specimens from 3 samples.

Description. Test medium to large in size, chambers numerous, later stages nearly planispiral and partly evolute, sutures slightly depressed. Wall thick, aperture interiomarginal.

Genus *Cribrostomoides* Cushman, 1910

Cribrostomoides subglobosus (Cushman, 1910)

Plate 38, fig. 8

Lituola subglobosa Cushman, 1910, p. 253.

Cribrostomoides subglobosus (Cushman). –Jones, Bender, Charnock, Kaminski & Whittaker, 1993, pl. 1, figs 1-5.

Cribrostomoides subglobosus subglobosus (Cushman). –Kaminski & Gradstein, 2005, p. 395, pl. 92, figs 1a-3b.

Occurrence. 19 specimens from 10 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Cribrostomoides* spp.**

Plate 39, fig. 1

Occurrence. 22 specimens from 16 samples.

Description. Test enrolled and involute, later stage becoming more planispiral. Wall thin to thick, simple in structure, surface smoothly to roughly finished. Aperture simple equatorial slit just above the base of the final chamber face, with a narrow

lip present on both margins. Sometimes becoming irregular with fine projections from both margins that may divide the primary aperture into a linear series of irregular to rounded openings near the base of the chamber face.

Genus *Recurvoides* Earland, 1934

Recurvoides azuaensis Bermúdez, 1949

Plate 39, figs 2,3

Recurvoides azuaensis Bermúdez, 1949, pl. 1, figs 35-37.

Occurrence. 45 specimens from 25 samples.

***Recurvoides* sp. 1**

Plate 39, figs 4,5

Occurrence. 9 specimens from 4 samples.

Description. Test small, consisting of 5 to 7 elongated chambers tightly enrolled to form spherical test. Coiling streptospiral becoming just off planispiral. Sutures slightly depressed. Aperture a basal slit. Wall coarse, with a rough finish. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Recurvoides* sp. 2**

Plate 38, fig. 6, Plate 39, fig. 6

Occurrence. 9 specimens from 6 samples.

Description. Test large, consisting of 5 chambers straptospirally enrolled, increasing in size rapidly. Periphery rounded, sutures straight and indistinct. Aperture basal surrounded by a coarse lip. Test wall very coarse. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Recurvoides* sp. 3**

Plate 39, figs 7-9

Occurrence. 47 specimens from 14 samples.

Description. Test medium to large in size, subglobular, tightly enrolled in a streptospiral, becoming almost planispiral. Last whorl consists of about 6 chambers increasing in size gradually. Wall thick, made up of coarsely agglutinated grains. Sutures indistinct from the surface topography, straight when viewed through the test wall. Aperture areal. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Recurvoides* spp.**

Plate 39, fig. 10

Occurrence. 75 specimens from 34 samples.

Description. Subglobular, streptospirally enrolled, generally few chambers per whorl, generally trochospiral to planispiral or may show an abrupt change in plane of coiling. Wall coarsely agglutinated, medium to thick, surface usually roughly finished, aperture areal.

Family AMMOBACULINIDAE Saidova, 1981

Subfamily AMMOBACULININAE Saidova, 1981

Genus *Bulbobaculites* Maync, 1952

***Bulbobaculites* sp. 1**

Plate 39, fig. 11

Occurrence. 1 specimen from 1 sample.

Description. Test of medium size, elongate, early stage with streptospirally enrolled globular and inflated chambers. Later chambers uncoiled and rectilinear, sutures distinct, depressed and horizontal. Wall coarsely finished and simple. Aperture terminal, a single small rounded opening.

Family PAVONTINIDAE Loeblich & Tappan, 1961

Subfamily SPIROPSAMMININAE Seiglie & Baker, 1984

Genus *Spiropsammina* Seiglie & Baker, 1984

Spiropsammina primula Seiglie & Baker, 1983

Plate 39, fig. 12, Plate 44, fig. 3

Spiropsammina primula Seiglie & Baker, 1983, pl. 2, figs 7-9.

Occurrence. 4 specimens from 4 samples.

Suborder Trochamminina Saidova 1981

Superfamily Trochamminacea Schwager 1877

Family Trochamminidae Schwager 1877

Subfamily Trochammininae Schwager 1877

Genus *Portatrochammina* Echols 1971

Portatrochammina profunda Kender, Kaminski and Jones

Plate 40, figs 1-5, Plate 47, figs 3-8

Portatrochammina profunda Kender, Kaminski & Jones, 2006, p. 468, pl. 2, figs 3-8.

Material: 206 species from 26 samples, Upper Oligocene.

Type specimens: Holotype (BMNH PF 67324) and paratypes (BMNH PF 67325) are deposited in the micropalaeontological collections of the Natural History Museum, London

Type localty: Congo Fan, offshore Angola, Block 31.

Type level: Cuttings sample 3,840 meters below rotary table. Oligocene black shales.

Derivation of name: After the Latin for 'deep', relating to its place of discovery in the distal part of the Congo Fan.

Description: Test free (up to 1mm diameter). Coiling low trochospiral (both dextral and sinistral) with 3-4 whorls and 4-4.5 chambers in each whorl. Chambers are inflated and increase in size rapidly so that the final whorl makes up most of the test. Sutures depressed. Wall thin, with a rough surface made up of predominantly medium grains containing occasional coarse inclusions. Specimens are invariably flattened. Aperture a low umbilical-facing opening covered by an umbilical flap. Cement siliceous, presumably organic before fossilisation.

Remarks: This species is similar to *Trochammina trincherasensis* Bermúdez, described from the Upper Oligocene of the Dominican Republic Trinchera Formation. *Trochammina trincherasensis* differs by having a typical trochamminid-like elongate apertural slit between the umbilicus and the periphery. It is described as having calcareous cement, although we believe it more probable that this is not the case. *Portatrochammina profunda* can occur in high abundance in the studied well.

Genus *Tritaxis* Schubert, 1921

***Tritaxis* sp. 1**

Plate 40, figs 6,7

Occurrence. 8 specimens from 5 samples.

Description. Test large, trochospiral, with 3 chambers in the final whorl making up the adult from. Sutures depressed, chambers globular. Wall thick and coarse, with a rough texture. Aperture interiomarginal, resting on the first chamber of the final whorl.

Genus *Trochammina* Parker & Jones, 1859

***Trochammina* sp. 1**

Plate 40, figs 8,9

Occurrence. 6 specimens from 3 samples.

Description. Test of medium size, consisting of 5 to 6 globular chambers trochospirally enrolled and

increasing in size gradually. Sutures radial. Wall thin, coarse, with a rough texture. Aperture interiomarginal opening resting on the first chamber of the final whorl.

***Trochammina* spp.**

Plate 40, fig. 10

Occurrence. 207 specimens from 35 samples.

Description. We include forms that are trochospiral, chambers increasing gradually in size, sutures radial, periphery rounded. Test small to large, aperture generally unseen. Wall coarse to fine, and thin to thick.

Family PROLIXOPLECTIDAE Loeblich & Tappan, 1985

Genus *Eggerelloides* Haynes, 1973

***Eggerelloides* sp. 1**

Plate 41, figs 1,2

Occurrence. 2 specimens from 2 samples.

Description. Test large in size, subfusiform, early stage of growth trochospiral, later triserial. Aperture a high interiomarginal arch in the centre of the apertural face, with a broad lip. Wall simple, thick, coarse, with a rough texture.

Genus *Karrerulina* Finlay, 1940

Karrerulina apicularis (Cushman, 1911)

Plate 41, figs 3,4

Gaudryina apicularis Cushman, 1911, p. 69, textfig. 110.

Karrerulina apicularis (Cushman). –Murray & Alve, 1994, pl. 1, fig. 13.

Occurrence. 12 specimens from 6 samples

Description. Test elongate and slender, initially trochospiral, later triserial becoming biserial. Chambers slightly inflated. Aperture terminal, at the end of a projected neck.

Karrerulina conversa (Grzybowski, 1901)

Plate 41, figs 5-6

Gaudryina conversa Grzybowski, 1901, p. 285, pl. 7, figs 15, 16.

Gerochammina conversa (Grzybowski). – Kaminski & Geroch, 1993, p. 279, pl. 13, figs 5a-11.

Karrerulina conversa (Grzybowski). –Kaminski & Gradstein, 2005, p. 472, pl. 116, figs 1a-11b.

Occurrence. 6 specimens from 3 samples.

Karrerulina horrida (Mjatliuk, 1970)

Plate 41, fig. 7

Karreriella horrida Mjatliuk, 1970, pl. 5, fig. 9, pl. 33, figs 15-16.

Karrerulina horrida (Mjatliuk) –Kaminski & Gradstein, 2005, p. 474, pl. 117, figs 1-11.

Occurrence. 2 specimens from 1 samples.

***Karrerulina* spp.**

Occurrence. 17 specimens from 9 samples.

Description. We include elongated slender specimens that are trochospirally coiled in the initial part and reduced in the latter stages.

Remarks. Generally not assigned to a species due to breakages or bad preservation.

Family REOPHACELLIDAE Mikhalevich & Kaminski, 2004

Subfamily VERNEUILININAE Cushman, 1911

Genus *Verneuilina* d'Orbigny, 1839

***Verneuilina* sp. 1**

Plate 41, fig. 8

Occurrence. 1 specimen.

Description. Test large, elongate conical in shape, chambers tricerial and triangular increasing rapidly in size. Wall simple, thick, and relatively smooth. Aperture an interiomarginal arch.

Family CYCLAMMINIDAE Marie, 1941

Subfamily ALVEOLOPHRAGMIINAE Saidova, 1981

Genus *Popovia* Suleymanov, 1965

***Popovia* sp. 1**

Plate 44, fig. 4

Occurrence. 10 specimens from 6 samples.

Description. Test large, planispiral, involute, with approximately 7 chambers in the final whorl. Periphery acute, test flattened, sutures indistinct from the outer layer. Wall bilamellar. Inner layer thin, thickened at the periphery, with one hemisepta protruding from the periphery into each chamber. Outer wall simple, thin, coarse grained.

***Popovia* spp.**

Occurrence. 22 specimens from 9 samples.

Description. We include planispiral forms uncoiling in later stages. Generally coarse wall with an alveolar subepidermal layer and simple septae.

Remarks. Generally badly preserved specimens that are as yet unassigned to a particular species.

Genus *Reticulophragmium* Maync, 1955

Reticulophragmium acutidorsatum (Hantken, 1868)

Plate 41, fig. 9, Plate 44, fig. 5, Plate 48, figs 1-7

Haplophragmium acutidorsatum Hantken, 1868, p. 82, pl. 1, fig. 1.

Reticulophragmium acutidorsatum (Hantken). – Kaminski & Gradstein, 2005, p. 490, pl. 122, figs 1-7.

Occurrence. 136 specimens from 40 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Reticulophragmium acutidorsatum* ssp. 1**

Plate 41, fig. 10, Plate 44, fig. 6

Occurrence. 1 specimen.

Description. Test large, involute planispiral, with 12 chambers in the last whorl. Chambers inflated, periphery acute. Sutures depressed at the periphery, straight, and angled away from the direction of coiling. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Reticulophragmium amplectens (Grzybowski, 1898)

Plate 41, fig. 11

Cyclammina amplectens Grzybowski, 1898, p. 292, pl. 12, figs 1-3.

Reticulophragmium amplectens (Grzybowski). – Kaminski & Geroch, 1993, p. 266, pl. 11, figs 5-7c.

Reticulophragmium amplectens (Grzybowski). – Kaminski & Gradstein, 2005, p. 495, pl. 123, figs 1-6.

Occurrence. 119 specimens from 34 samples. Occurs throughout most of the well, maxima between 4050-4130m.

Remarks. We include forms that are medium to large, thick, have an acute (almost carinate) periphery, an umbilical depression, and have elongated radial alveoles. Some specimens show a

highly-silicified wall and may be reworked from the Eocene.

***Reticulophragmium amplectens* ssp. 1**

Plate 41, fig. 12, Plate 44, figs 7,8

Occurrence. 6 specimens from 5 samples.

Description. Large, thick, acute periphery, straight depressed sutures, depressed umbilicus. Alveoles are elongated and radial in appearance. Test smooth.

Remarks. This form differs from *R. amplectens* (Grzybowski) by its larger size and less acute periphery. It appears that *R. amplectens* ssp. 1 may have evolved from a transitional form of *R. acutidorsatum* (Hantken) due to its otherwise close appearance. This would indicate that elongated alveoles have evolved more than once and are thus an example of convergent evolution as *R. amplectens* first appears in the Early Eocene. Some specimens show a highly-silicified wall however, and may be reworked from the Eocene.

***Reticulophragmium amplectens / acutidorsatum* transitional form**

Plate 42, fig. 1, Plate 44, figs 9,10

Occurrence. 9 specimens from 8 samples.

Description. Test large, involute, planispiral, with 12-14 chambers in the final whorl. Periphery acute (almost carinate), sutures depressed and straight, umbilicus depressed. Test wall is composed of primarily rounded and sometimes elongated alveoles.

Remarks. This form is transitional between rounded and elongated alveoles, showing this test feature has evolved more than once. Forms of *R. amplectens* with elongated alveoles first appear in the Early Eocene. Some specimens show a highly-silicified wall however, and may be reworked from the Eocene.

***Reticulophragmium gasparense* (Bermúdez, 1949) emend.**

Plate 42, fig. 3

Cyclammina gasparensis Bermúdez, 1949, pl. 1, figs 47,48.

Occurrence. One complete form present, numerous broken cyclamminids throughout the well which may be *Cyclammina gasparensis*.

Remarks. This species is here transferred to the genus *Reticulophragmium* Maync due to the absence of true supplementary apertures. The form is otherwise very similar to *Cyclammina* sp. 1 and *Cyclammina* sp. 2 in size, shape and wall structure.

***Reticulophragmium intermedium* (Mjatliuk, 1970)**

Plate 42, fig. 2, Plate 45, figs 1-3

Cyclammina (?) *intermedia* Mjatliuk, 1970, p. 89, pl. 21, figs 1a-c.

Reticulophragmium intermedium (Mjatliuk). – Kender, Kaminski & Cieszkowski, 2005, p. 267, figs 13I, J.

Reticulophragmium intermedium (Mjatliuk). – Kaminski & Gradstein, 2005, p. 500, pl. 125, figs 1a-5b.

Occurrence. 14 specimens from 5 samples.

Remarks. Specimens generally show a highly-silicified wall and may be reworked from the Eocene.

***Reticulophragmium rotundidorsatum* (Hantken, 1875)**

Plate 42, figs 4,5, Plate 48, fig. 8

Haplophragmoides rotundodorsatum Hantken, 1875, p. 12, pl. 1, fig. 2.

Cyclammina (Reticulophragmium) rotundidorsatum (Hantken). – Charnock & Jones, 1990, pl. 7, figs. 13-15, pl. 19, fig. 1.

Reticulophragmium rotundidorsatum (Hantken). – Cicha, Rögl, Rupp & Ctyroka, 1998, pl. 5, fig. 5.

Reticulophragmium rotundidorsatum (Hantken). – Kaminski & Gradstein, 2005, p. 507, pl. 127, figs 1a-5c.

Occurrence. 256.5 specimens from 44 samples.

Remarks. Some specimens show a highly-silicified wall and may be reworked from the Eocene.

***Reticulophragmium* sp. 1**

Plate 42, fig. 6

Occurrence. 6 specimens from 4 samples.

Description. Test medium to small in size, involute planispiral, with 5 bead-like chambers in the final whorl. Periphery rounded. Sutures straight and depressed. Aperture indistinct. Wall thin, bilamellar, inner wall alveolar. Test usually flattened due to thin wall.

Remarks. *Reticulophragmium* sp. 1 is probably a 'primitive' evolutionary form of the genus, and may have evolved form the *Haplophragmoides* Cushman as it exhibits only a very thin alveolar wall.

***Reticulophragmium* spp.**

Occurrence. 73.5 specimens from 34 samples.

Description. We include all forms that are planispiral, with a complex bilamellar wall. Inner wall contains alveoles, outer wall simple, smooth with a fine finish. Apertural a basal lip.

Remarks. Poor preservation did not enable us to assign these forms to particular species.

Family CYCLAMMINIDAE Marie, 1941

Subfamily CYCLAMMININAE Marie, 1941

Genus *Cyclammina* Brady, 1879

Cyclammina* aff. *orbicularis Brady, 1884

Plate 42, figs 7-8

Cyclammina orbicularis Brady, 1884, p. 353, pl. 37, figs 17-18.

Occurrence. 2 specimens from 2 samples.

Remarks. These specimens resemble *R. orbicularis*, but bad preservation of apertural face hampers identification.

***Cyclammina* sp. 1**

Plate 43, fig. 1

Cyclammina (Cyclammina) acutidorsata (Hantken). –Charnock & Jones, 1997, p. 188, fig. 6, figs 2a-c.

Occurrence. 2 specimens from 2 samples.

Description. Test large, involute, planispiral, with 12-14 chambers in the final whorl. Test approx. half as thick as it is wide. Megalospheric forms have fewer chambers in the final whorl than the microspheric forms. Periphery acute, sutures depressed and sigmoidal in later stages, umbilicus depressed. Apertural face large, convex, containing coarse grains. Primary aperture is a basal slit covered by a small lip. A single round supplementary aperture is present in the centre of the apertural face, sometimes surrounded by a raised lip. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks. This species is distinct due to its single supplementary aperture in the centre of the apertural face, and differs from *C. cyclops* McNeil (1988) by having a much thicker test, larger apertural face and more involute coiling. Charnock

& Jones (1997) also illustrate this species from the North Sea, and class it under the name *Cyclammina acutidorsata* (Hantken), along with other specimens containing more supplementary apertures but with an otherwise similar morphology.

***Cyclammina* sp. 2**

Plate 43, figs 2,3

Cyclammina sp. Kaminski, Silye & Kender, 2005, p. 395, pl. 7, figs 3a-c.

Occurrence. 2 specimens from 2 samples.

Description. Test large, involute, planispiral, with 10-13 chambers in the final whorl. Test approx. half as thick as it is wide. Megalospheric forms have fewer chambers in the final whorl than the microspheric forms. Periphery acute, sutures depressed and sigmoidal in later stages, umbilicus depressed. Apertural face large, convex, containing coarse grains. Primary aperture is a basal slit covered by a small lip. Four round supplementary apertures are present in the centre of the apertural face forming a 'diamond' arrangement, and are surrounded by raised lips. Test wall is composed of two layers. The inner hypodermal layer is thick and perforated by tubular alveoles, the outer layer is thin and fine-grained with a smooth finish.

Remarks. This species is distinct due to its four supplementary apertures on the apertural face, arranged in an oblique 'diamond' pattern. Charnock & Jones (1997) have found similar cyclamminids from the North Sea and generally grouped them under *Cyclammina acutidorsata* (Hantken).

***Cyclammina* spp.**

Occurrence. 22.5 specimens from 12 samples.

Remarks. Most of these specimens strongly resemble either *R. gasparensis*, or *Cyclammina* sp.1 or sp.2. They do not, however, have the apertural face preserved.

Family TEXTULARIELLIDAE Grönhagen & Luterbacher, 1966

Genus *Alveovalvulina* Brönnimann, 1953

***Alveovalvulina* sp. 1**

Plate 43, fig. 5

Occurrence. 1 specimen.

Description. Test large, increasing in size rapidly. Coiling trochospiral in the early stage, becoming triserial. Chambers inflated, sutures depressed. Wall coarse, with complex alveolar inner structure. Aperture a low interiomarginal arch.

***Alveovalvulina* spp.**

Plate 43, fig. 4

Occurrence. 1 specimen.

Description. The form exhibits a trochospiral early stage, becoming triserial. Test large. Wall coarse, with complex alveolar structure. Aperture a low interiomarginal arch.

Genus *Alveovalvulinella* Brönnimann, 1953

Alveovalvulinella crassa (Cushman & Renz, 1941)

Plate 43, figs 6,7

Liebusella pozonensis var. *crassa* Cushman & Renz, 1941, p. 10, pl. 2, figs 3, 4.

Alveovalvulinella pozonensis var. *crassa* (Cushman & Renz). –Bolli et al., 1994, pl. 76, figs 30-31

Occurrence. 2 specimens from 1 sample.

Family EGGERELLIDAE Cushman, 1937

Subfamily EGGERELLINAE Cushman, 1937

Genus *Karreriella* Cushman, 1933

***Karreriella* spp.**

Occurrence. 7 specimens from 4 samples.

Description. Test small to medium in size, elongate, trochospiral becoming biserial. Wall canaliculate, coarse to medium grained, generally with a rough finish. Aperture terminal.

Family VALVULINIDAE Berthelin, 1880
Subfamily VALVULININAE Berthelin, 1880
Genus *Valvulina* d'Orbigny, 1826

Valvulina flexilis Cushman & Renz, 1941

Plate 43, fig. 8

Valvulina flexilis Cushman & Renz, 1941, p. 7, pl. 1, figs 16-17.

Occurrence. 1 specimen.

***Valvulina* spp. early form**

Occurrence. 1 specimen.

Description. Test medium to small in size, triserial, chambers triangular with flattened sides. Wall canaliculate, thin, medium grained with smooth finish. Aperture interiomarginal.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus *Haeuslerella* Parr, 1935

***Haeuslerella* sp. 1**

Plate 43, fig. 9

Occurrence. 3 specimens from 3 samples.

Description. Medium to small in size, elongate, biserial, later alternating in a loose biserial arrangement. Sutures distinct, depressed. Chambers globular. Wall thin, coarse, with a rough texture. Aperture nearly terminal and rounded.

Genus *Textularia* Defrance, 1824

Textularia earlandi Parker, 1952

Plate 43, figs 10,11

Textularia tenuissima Earland, 1933, p. 95, pl. 3, figs 21-30.

Textularia earlandi Parker, 1952, p. 458.

Occurrence. 37.5 specimens from 14 samples.

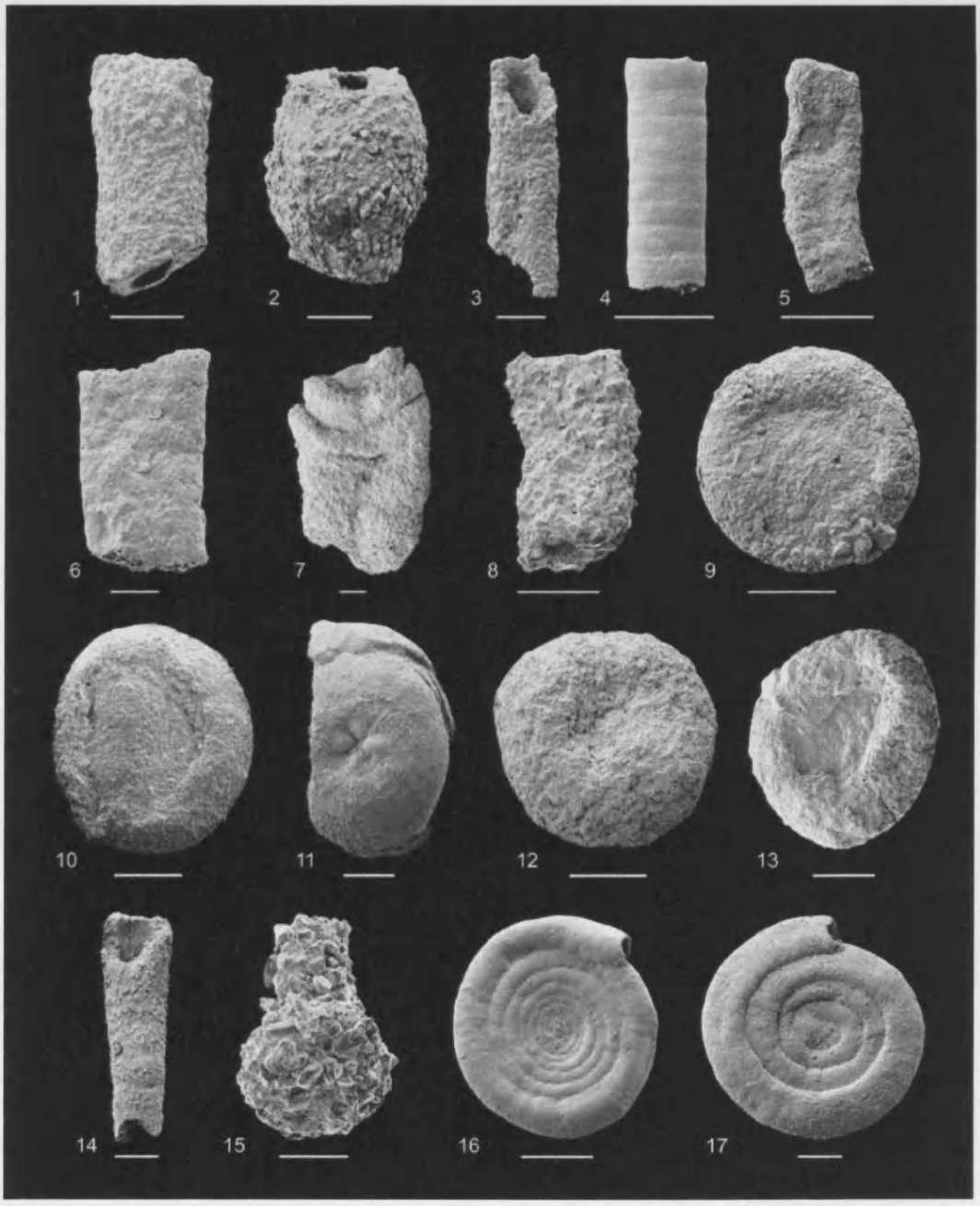


Plate 1. 1. *Psammosiphonella cylindrica*, 4100m **2.** *Rhabdammina linearis*, 2820m **3.** *Rhabdammina* sp.1, 2840m **4.** *Bathysiphon* sp., 2840m **5.** *Nothia excelsa*, 2840m **6.** *Nothia latissima*, 3750m **7.** *Nothia robusta*, 3740m **8.** *Rhizammina* sp., 4160m **9.** *Saccammina* cf. *sphaerica*, 3840m **10.** *Saccammina* sp.1, 3810m **11.** Unassigned form, 2870m **12.** *Psammosphaera* cf. *fusca*, 3850m **13.** *Psammosphaera* sp.1, 3800m **14.** *Jaculella* sp.1, 3030m **15.** *Hyperammina elongata*, 4010m **16.** *Ammodiscus cretaceus*, 3200m **17.** *Ammodiscus latus*, 3090m. Scale bar = 200 μm. All specimens from well Plutao-1.

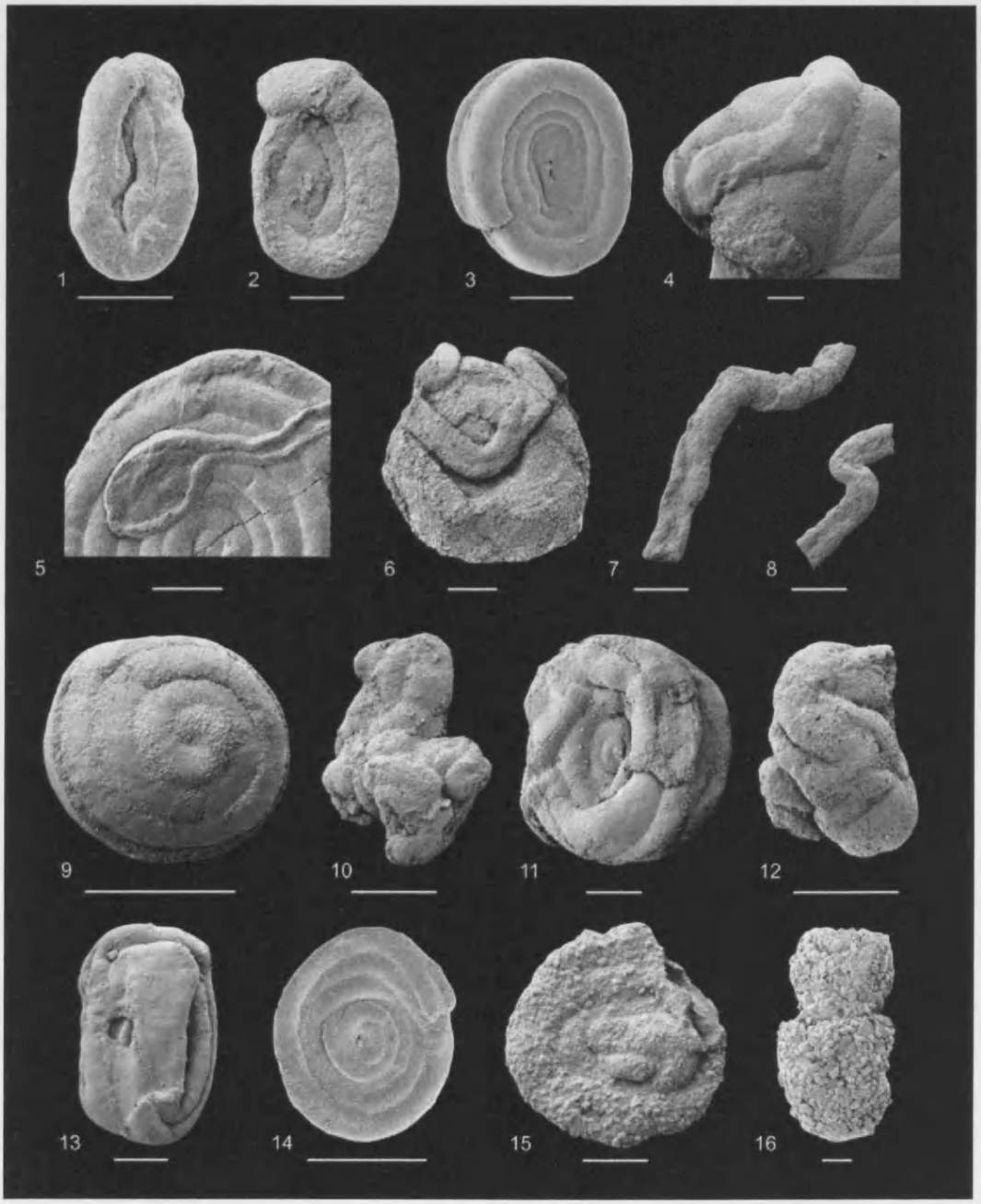


Plate 2. 1. *Ammodiscus* aff. *peruvianus*, 3850m **2.** *Ammodiscus* aff. *peruvianus*, 3340m **3.** *Ammodiscus glabratus*, 3020m **4.** *Ammolagena clavata* (attached to *Cyclammina cancellata*), 2810m **5.** *Ammolagena clavata* (attached to *Ammodiscus cretaceus*), 3830m **6.** *Ammolagena clavata* (attached to *Psammosphaera* sp.), 3020m **7.** *Tolypammina* sp., 2810m **8.** *Tolypammina* sp., 2810m **9.** *Glomospira charoides*, 2900m **10.** *Glomospira glomerata*, 3030m **11.** *Glomospira gordialis*, 3180m **12.** *Glomospira irregularis*, 2820m **13.** *Glomospira* aff. *serpens*, 3100m **14.** *Glomospira* sp.1, 3810m **15.** *Glomospira* sp.2, 3850m **16.** *Hormosinella carpenteri*, 3900m. Scale bar = 200 μm. All specimens from well Plutao-1.

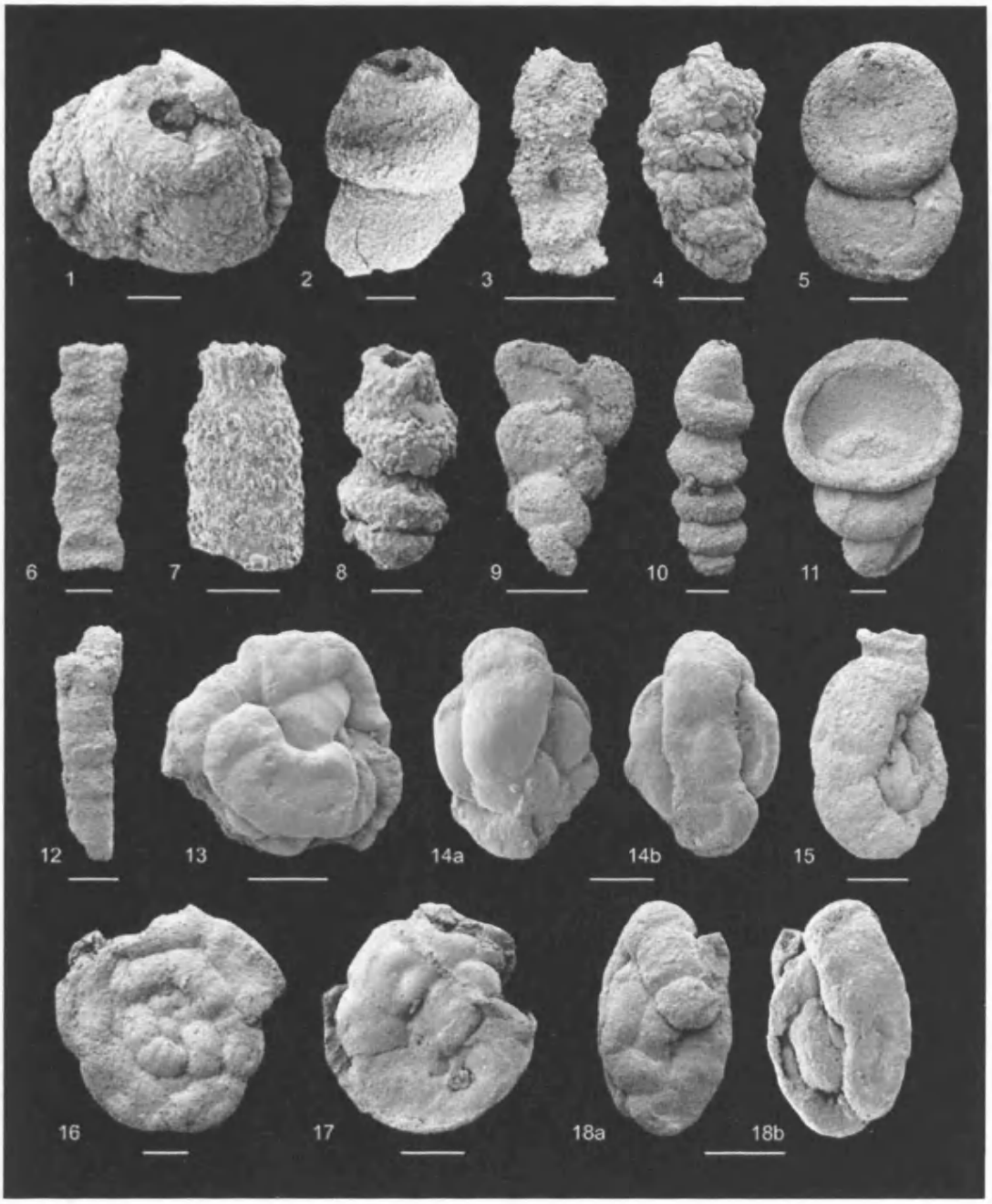


Plate 3. 1. *Reophanus berggreni*, 3850m **2.** *Reophanus* aff. *berggreni*, 3010m **3.** *Subreophax scalaris*, 3030m **4.** *Subreophax scalaris*, 2810m **5.** *Aschemocella grandis*, 2840m **6.** *Subreophax* sp.1, 3200m **7.** *Kalamopsis* sp., 4030m **8.** *Hormosinelloides guttifer*, 3840m **9.** *Reophax pilulifer*, 2860m **10.** *Hormosina glabra*, 3100m **11.** *Hormosina globulifera*, 3120m **12.** *Pseudonodosinella nodulosa*, 2900m **13.** *Lituotuba lituiformis*, 2810m **14.** *Lituotuba lituiformis*, 3240m **15.** *Lituotuba lituiformis*, 3010m **16.** *Paratrochamminoides challengeri*, 3060m **17.** *Paratrochamminoides deflexiformis*, 3150m **18.** *Paratrochamminoides gorayskiformis*, 3850m. Scale bar = 200 μm. All specimens from well Plutao-1.

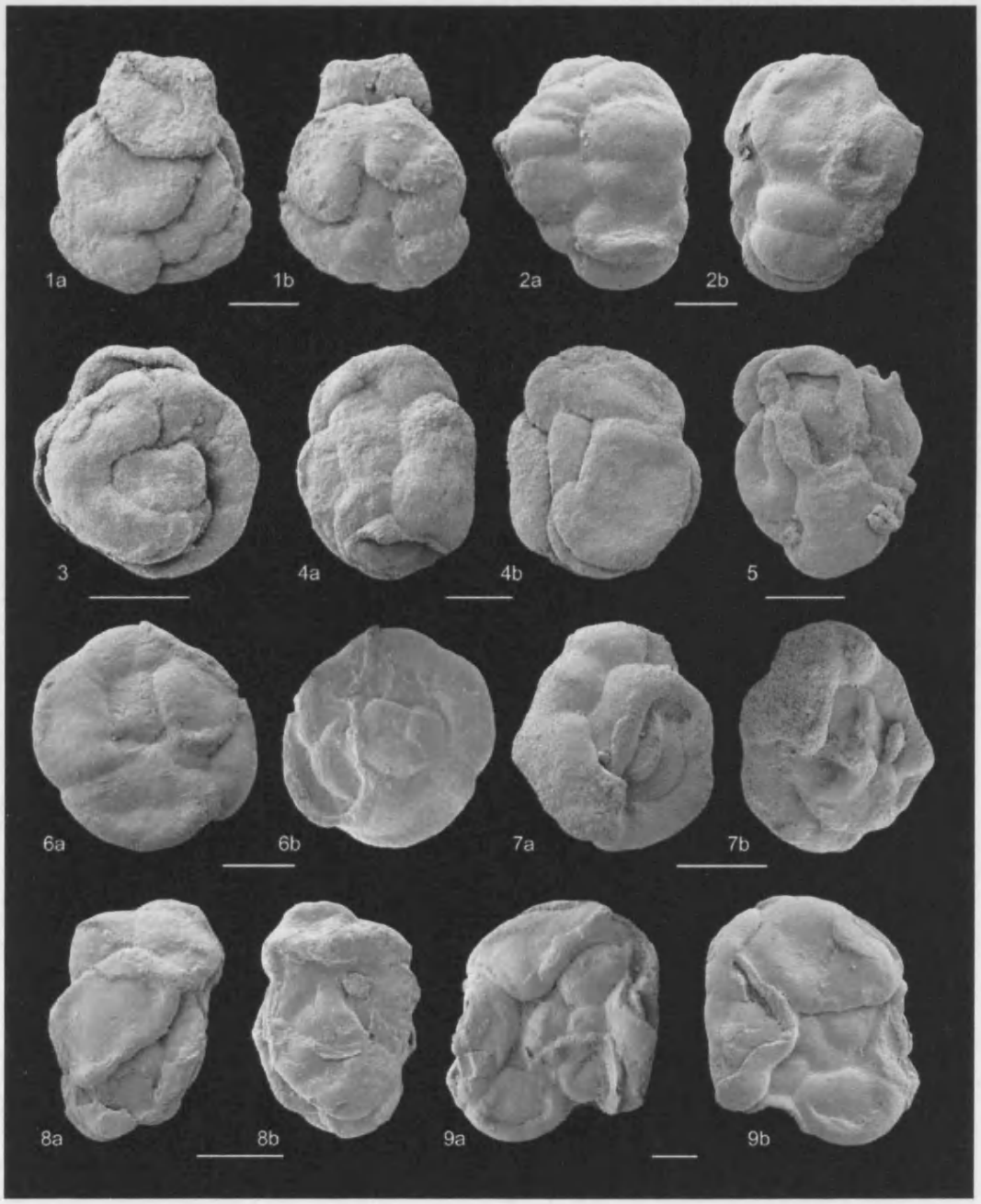


Plate 4. 1. *Paratrochamminoides heteromorphus*, 2810m **2.** *Paratrochamminoides mitratus*, 3030m **3.** *Paratrochamminoides olszewskii*, 3800m **4.** *Paratrochamminoides* sp.1, 2810m **5.** *Paratrochamminoides* sp.1, 3230m **6.** *Paratrochamminoides* sp.1, 3030m **7.** *Paratrochamminoides* sp.1,3230m **8.** *Paratrochamminoides* sp.1, 3080m **9.** *Paratrochamminoides* sp.1, 3030m. Scale bar = 200 μm. All specimens from well Plutao-1.

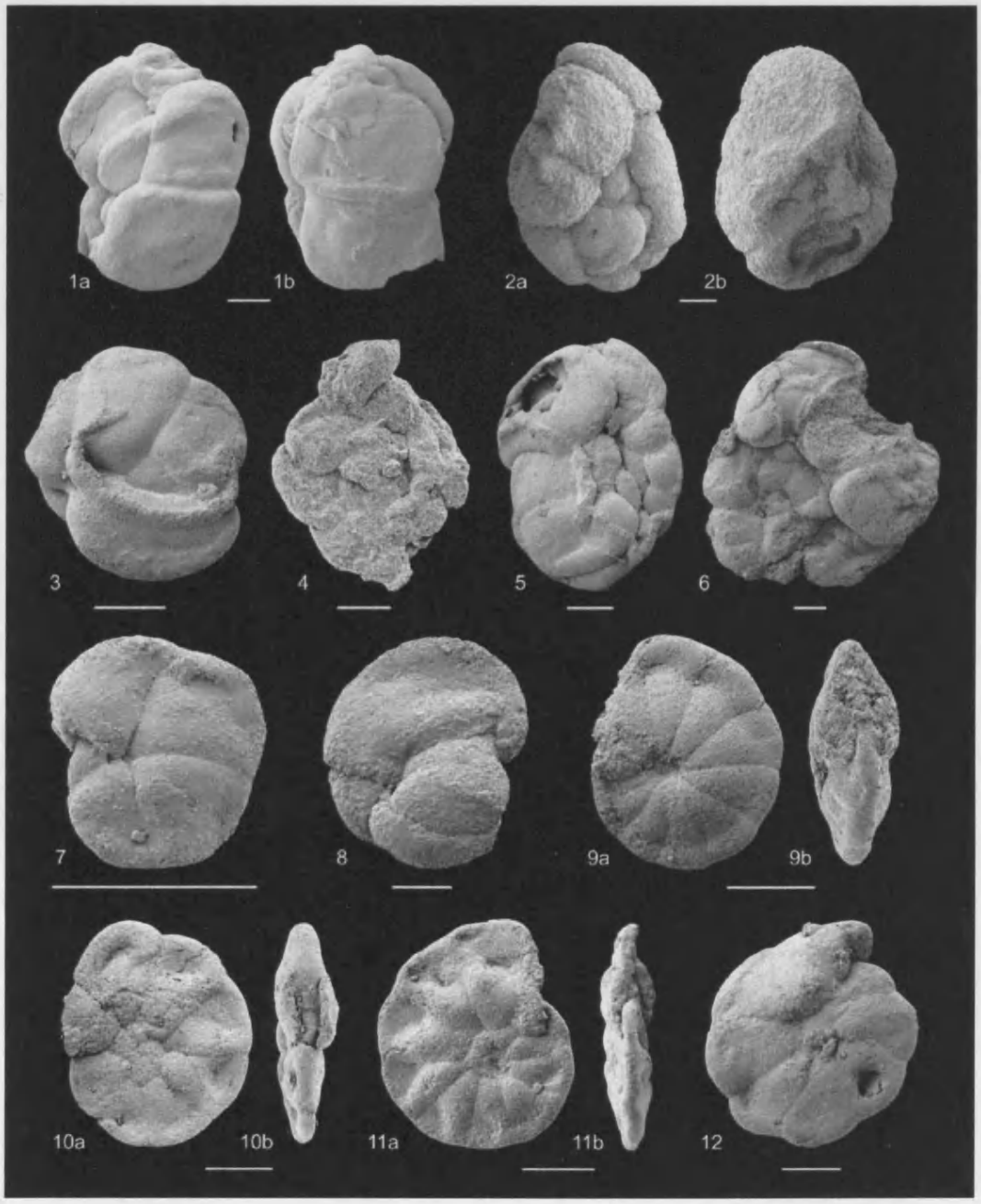


Plate 5. 1. *Paratrochamminoides* sp.1, 3030m **2.** *Paratrochamminoides* sp.1, 3040m **3.** *Conglophragmium irregulare*, 3020m **4.** *Trochamminoides folius*, 3960m **5.** *Trochamminoides subcoronatus*, 3140m **6.** *Trochamminoides subcoronatus*, 3250m **7.** *Haplophragmoides* cf. *bradyi*, 2810m **8.** *Haplophragmoides horridus*, 3100m **9.** *Haplophragmoides carinatus*, 2900m **10.** *Haplophragmoides nauticus*, 3030m **11.** *Haplophragmoides nauticus*, 3840m **12.** *Haplophragmoides nauticus*, 3060m. Scale bar = 200 μm. All specimens from well Plutao-1.

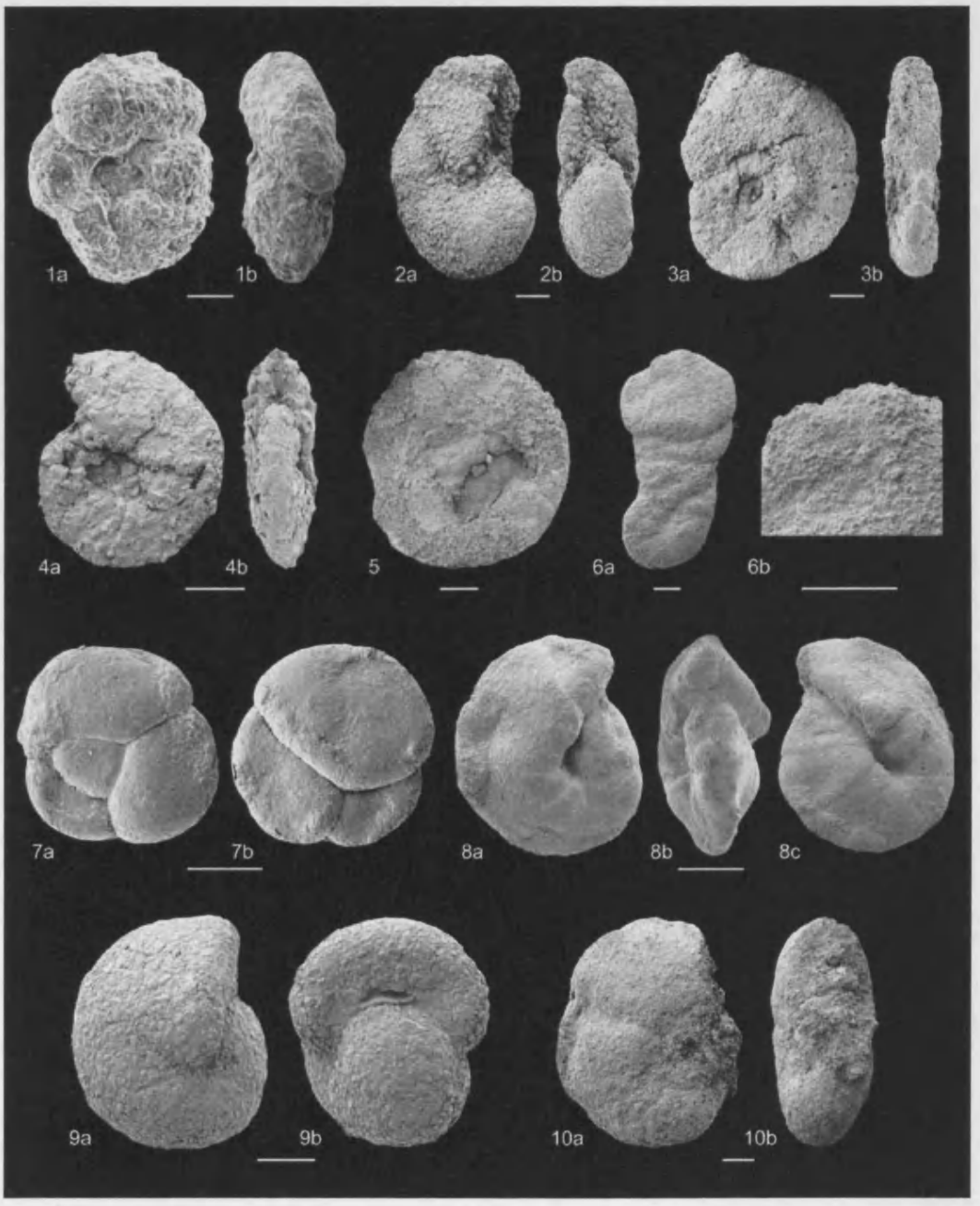


Plate 6. 1. *Haplophragmoides* sp.1, 3990m **2.** *Haplophragmoides* sp., 3120m **3.** *Glaphyrammina americana*, 3180m **4.** *Glaphyrammina americana*, 3100m **5.** *Praesphaerammina* sp.1, 3300m **6.** *Discamminoides* sp.1, 4030m **7.** *Ammosphaeroidina pseudopauciloculata*, 3850m **8.** *Budashevaella multicamerata*, 3100m **9.** *Cribrostomoides subglobosus*, 3100m **10.** *Cribrostomoides* sp.1, 2890m. Scale bar = 200 μm. All specimens from well Plutao-1.

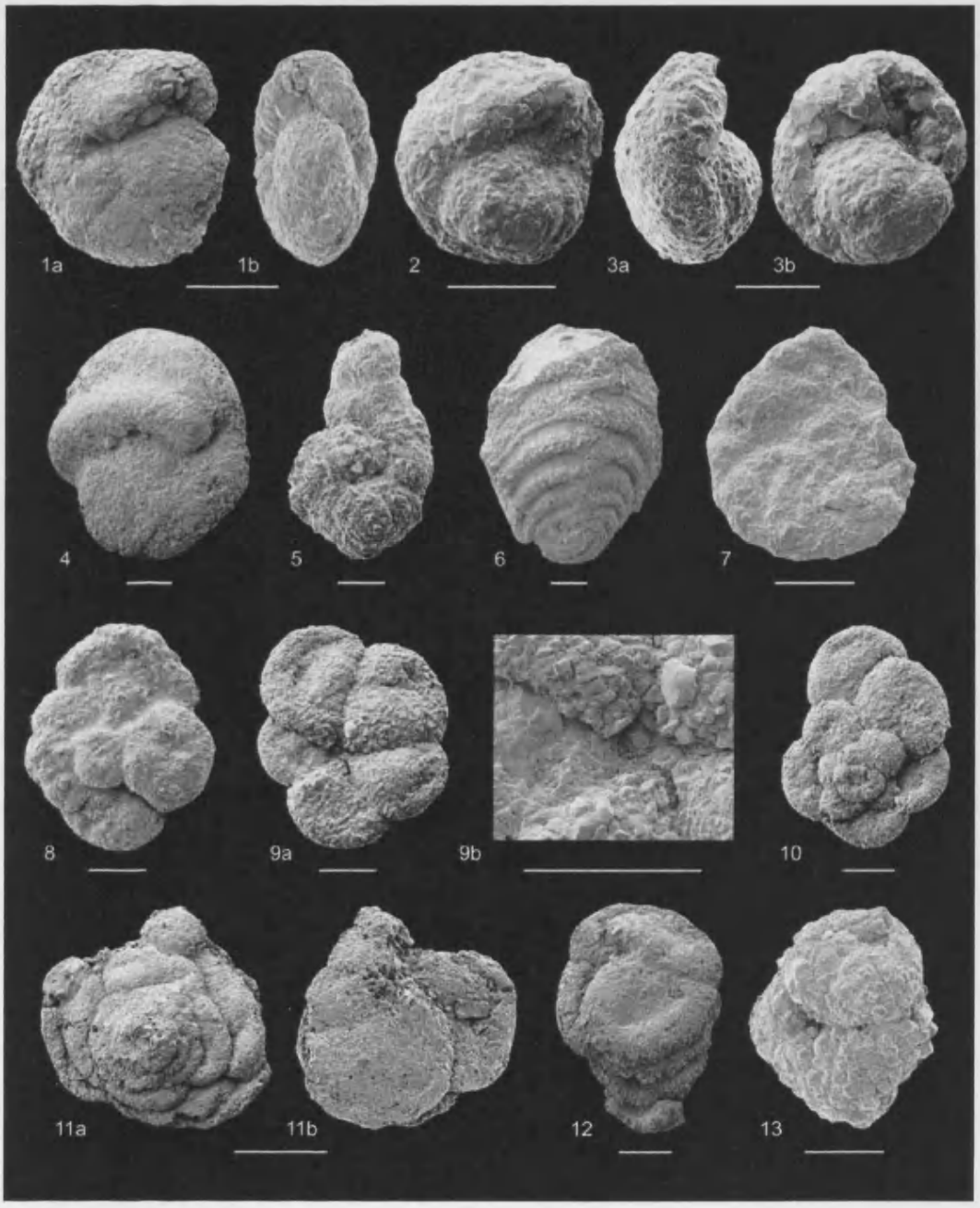


Plate 7. 1. *Recurvoides azuaensis*, 2900m **2.** *Recurvoides* sp.1, 3860m **3.** *Recurvoides* sp.1, 3860m **4.** *Recurvoides azuaensis*, 3760m **5.** *Bulbobaculites* sp.1, **6.** *Vulvulina miocenica*, 3200m **7.** *Spiropsammina primula*, 3860m **8.** *Portatrochammina profunda*, 3860m **9.** *Portatrochammina profunda*, 3840m **10.** *Portatrochammina profunda*, 3830m **11.** *Trochammina* sp.2, 3060m **12.** *Trochammina* sp.2, 2810m **13.** *Trochammina* sp.1, 3820m. Scale bar = 200 μm. All specimens from well Plutao-1.

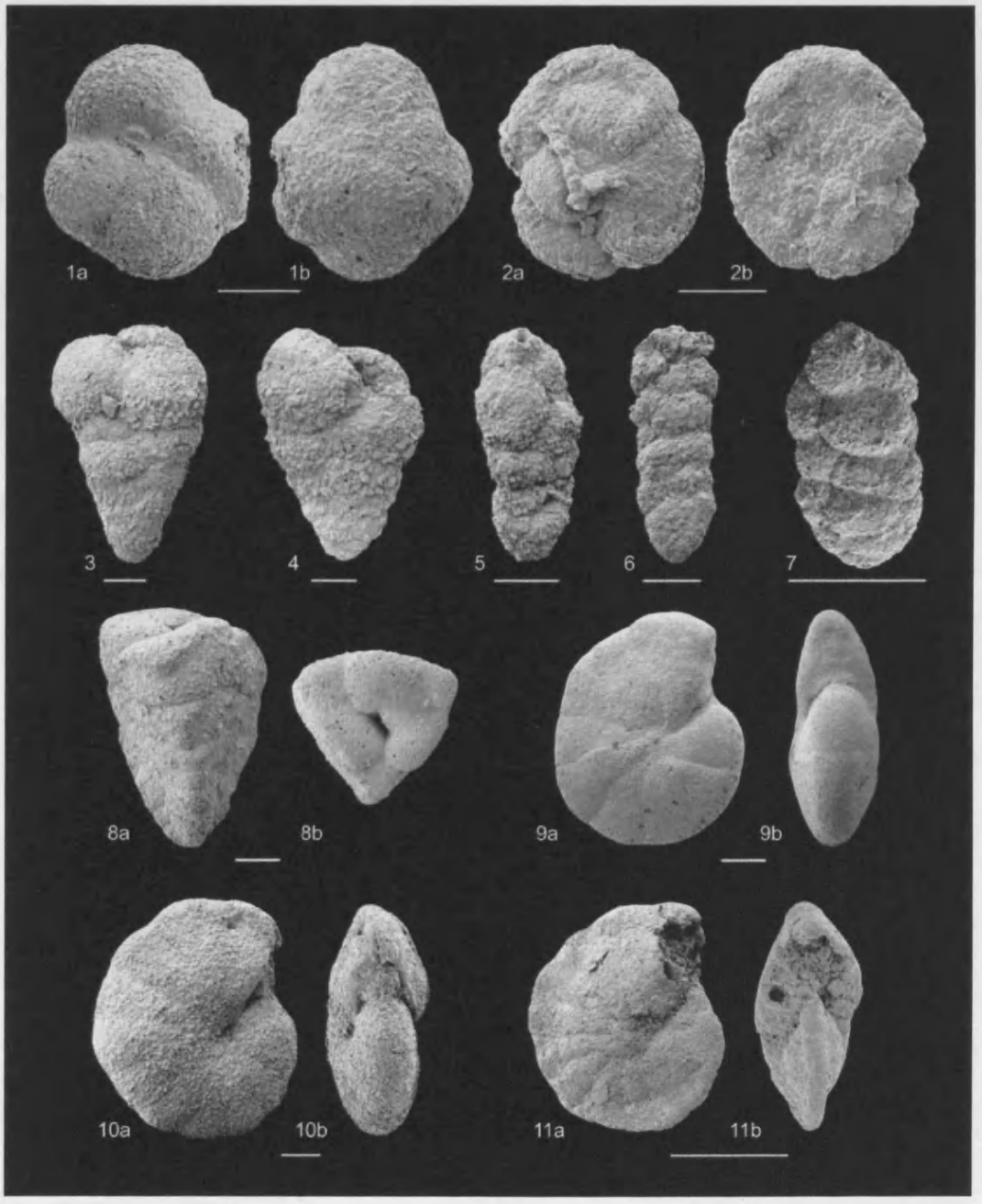


Plate 8. 1. *Trochammina* sp.4, 3350m **2.** *Ammosphaeroidina* sp., 2900m **3.** *Eggerelloides* sp.1, 3130m **4.** *Eggerelloides* sp.1, 2900m **5.** *Karrerulina apicularis*, 2810m **6.** *Karrerulina apicularis*, 3100m **7.** *Karrerulina apicularis*, 2810m **8.** *Gaudryina atlantica*, 3120m **9.** *Reticulophragmium acutidorsatum*, 3750m **10.** *Reticulophragmium acutidorsatum* ssp.1, 3330m **11.** *Reticulophragmium amplectens*, 2850m. Scale bar = 200 µm. All specimens from well Plutao-1.

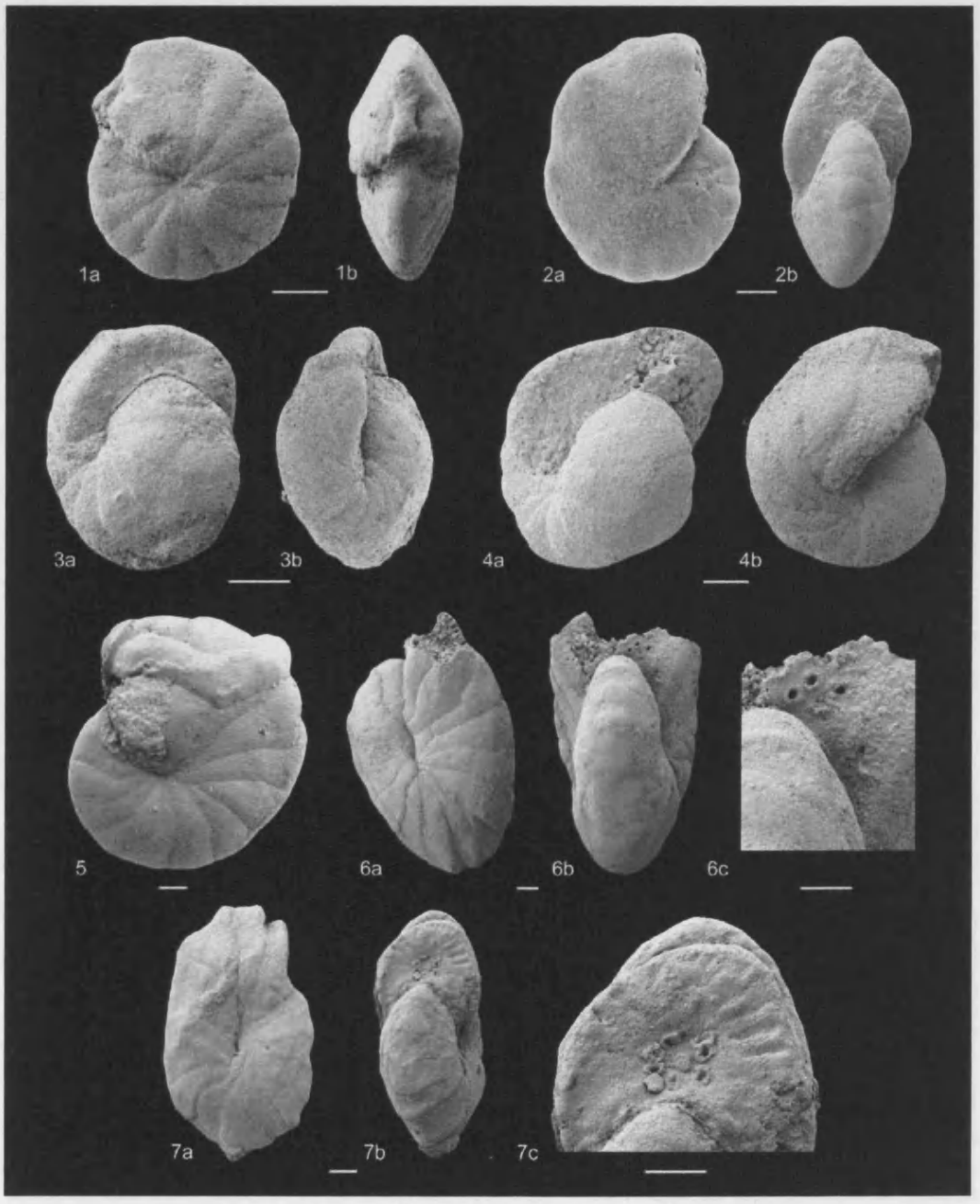


Plate 9. 1. *Reticulophragmium amplectens* ssp.1, 3860m **2.** *Reticulophragmium gasparense*, 3840m **3.** *Reticulophragmium rotundidorsatum*, 2900m **4.** *Reticulophragmium orbiculare*, 2810m **5.** *Cyclammina cancellata* (with attached *Ammolagena clavata*), 2810m **6.** *Cyclammina cancellata*, 2850m **7.** *Cyclammina cancellata* ssp.1, 3110m. Scale bar = 200 μm. All specimens from well Plutao-1.

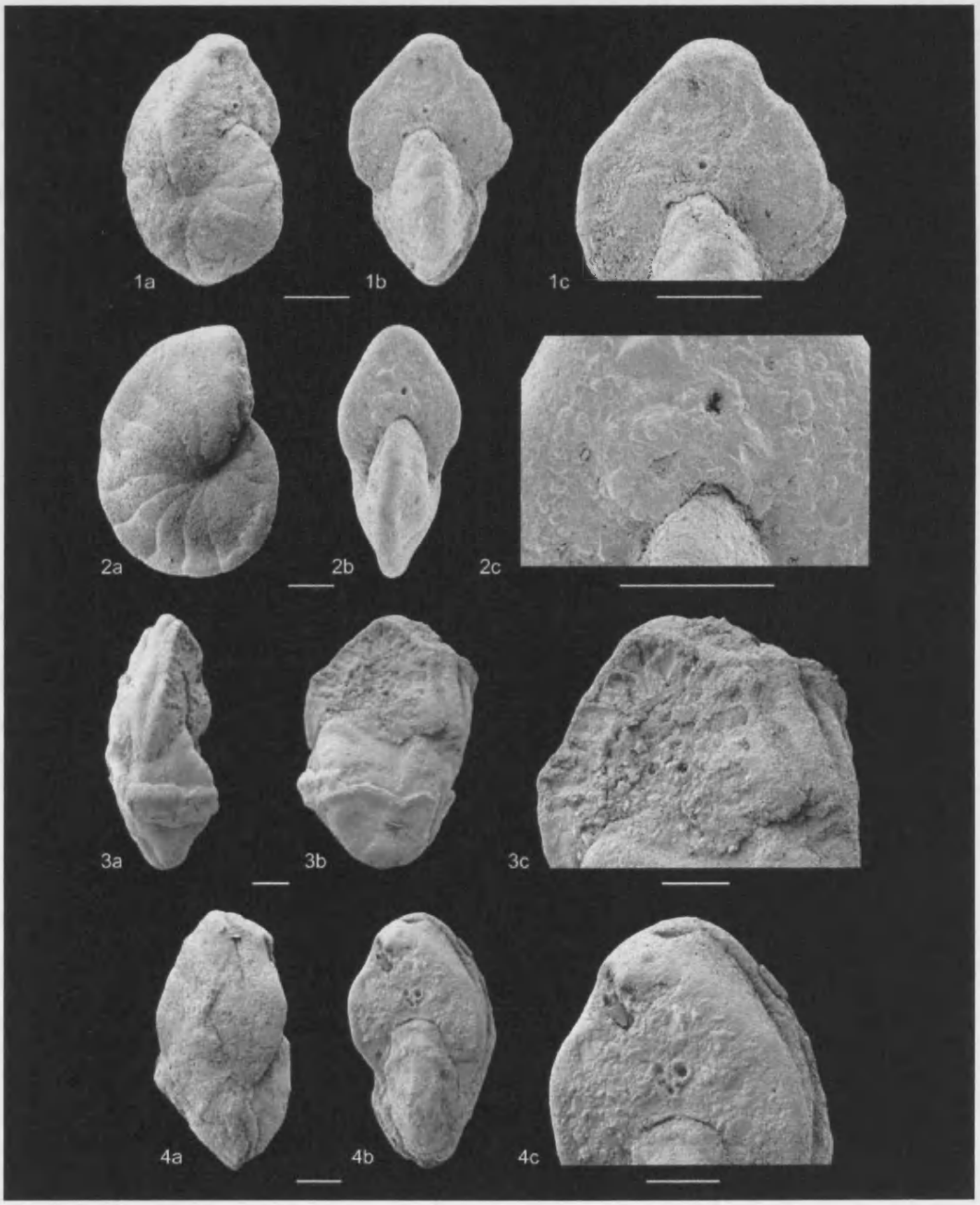


Plate 10. 1. *Cyclammina* sp.1, 3120m **2.** *Cyclammina* sp.1, 3040m **3.** *Cyclammina* sp.1, 3180m **4.** *Cyclammina* sp.2, 3100m. Scale bar = 200 μm. All specimens from well Plutao-1.

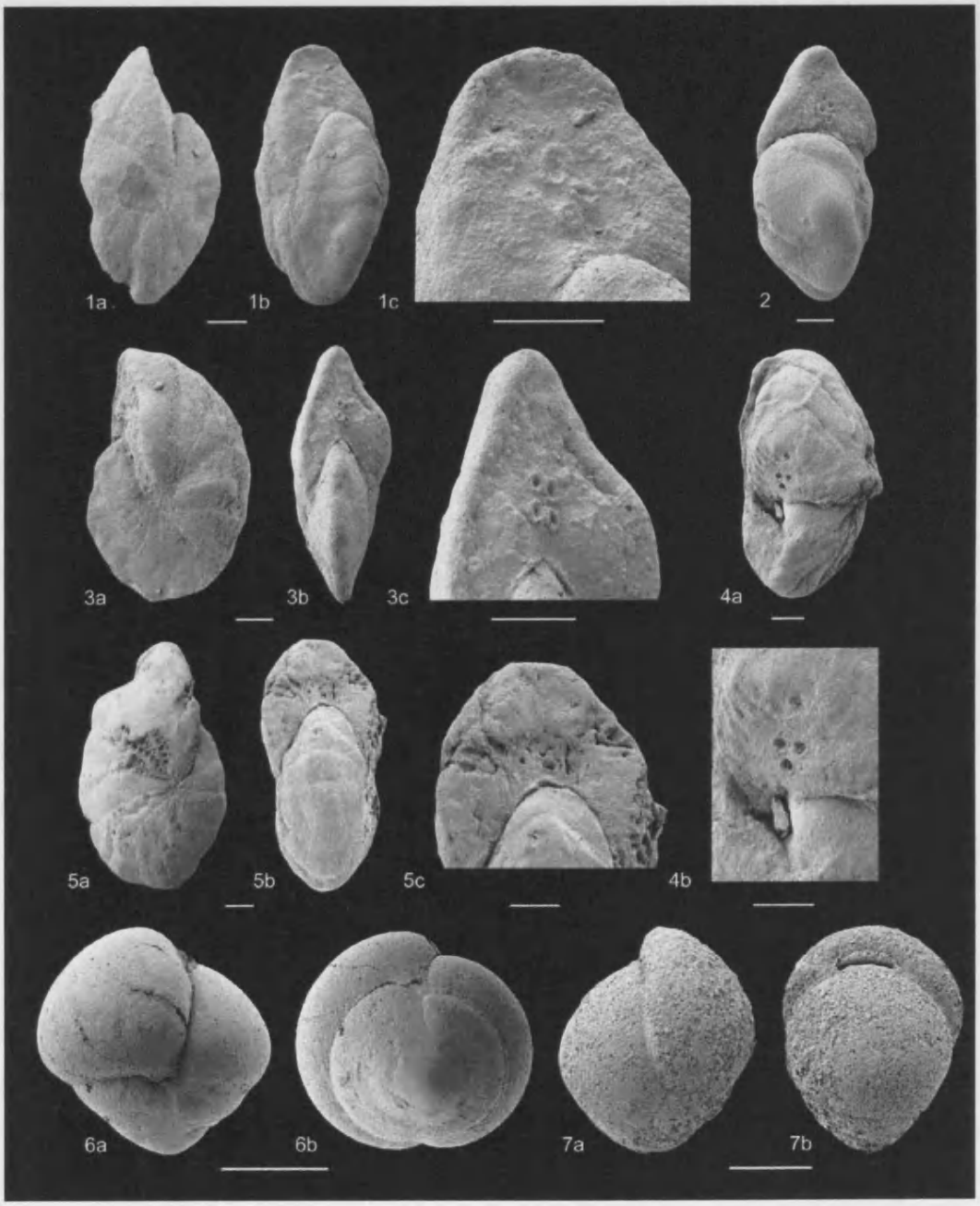


Plate 11. 1. *Cyclammina* sp.2, 3100m **2.** *Cyclammina* sp.2, 3930m **3.** *Cyclammina* sp.2, 3040m **4.** *Cyclammina* sp.2, 3080m **5.** *Cyclammina* sp.2, 3100m **6.** *Dorothia brevis*, 3120m **7.** *Dorothia brevis*, 3360m. Scale bar = 200 μm. All specimens from well Plutao-1.

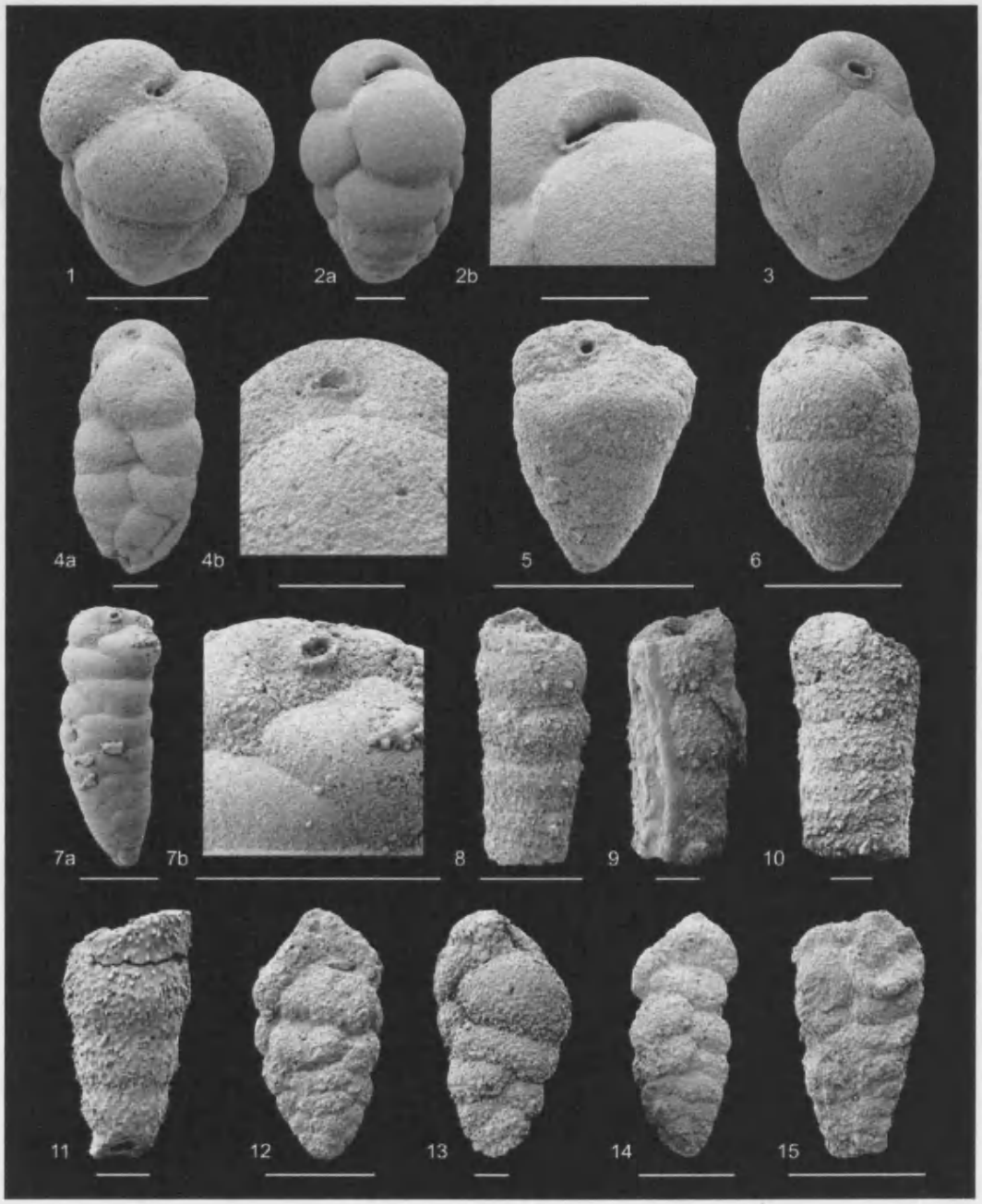


Plate 12. 1. *Eggerella bradyi*, 2920m **2.** *Eggerella bradyi*, 3170m **3.** *Karreriella* aff. *bradyi*, 3130m **4.** *Karreriella* aff. *bradyi*, 3130m **5.** *Karreriella microgranulosa*, 3070m **6.** *Karreriella microgranulosa*, 3050m **7.** *Karreriella microgranulosa*, 3140m **8.** *Martinotiella communis*, 3140m **9.** *Martinotiella communis* (with attached *Ammolagena clavata*), 3170m **10.** *Martinotiella communis*, 3330m **11.** *Martinotiella* sp., 3140m **12.** *Valvulina flexilis*, 3040m **13.** *Valvulina flexilis*, 3110m **14.** *Bigenerina* sp., 3150m **15.** *Textularia earlandi*, 3860m. Scale bar = 200 μm. All specimens from well Plutao-1.

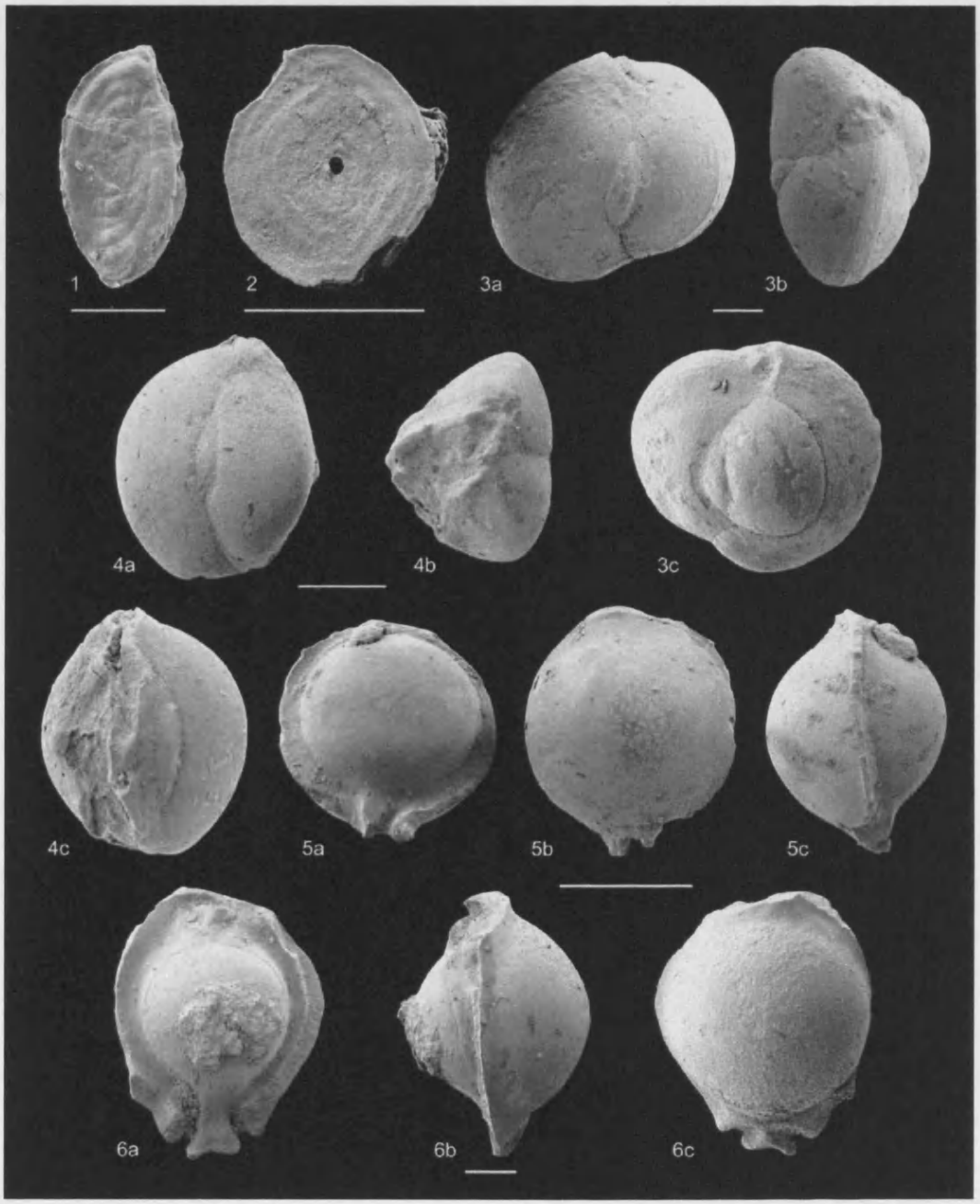


Plate 13. 1. *Opthalmidium* sp.A, 3250m **2.** *Spiroloculina excavata*, 3070m **3.** *Quinqueloculina triloculiniforma*, 2780m **4.** *Quinqueloculina triangularis*, 2910m **5.** *Pyrgo magnacaudata*, 2920m **6.** *Pyrgo* sp., 2790m. Scale bar = 200 μm. All specimens from well Plutao-1.

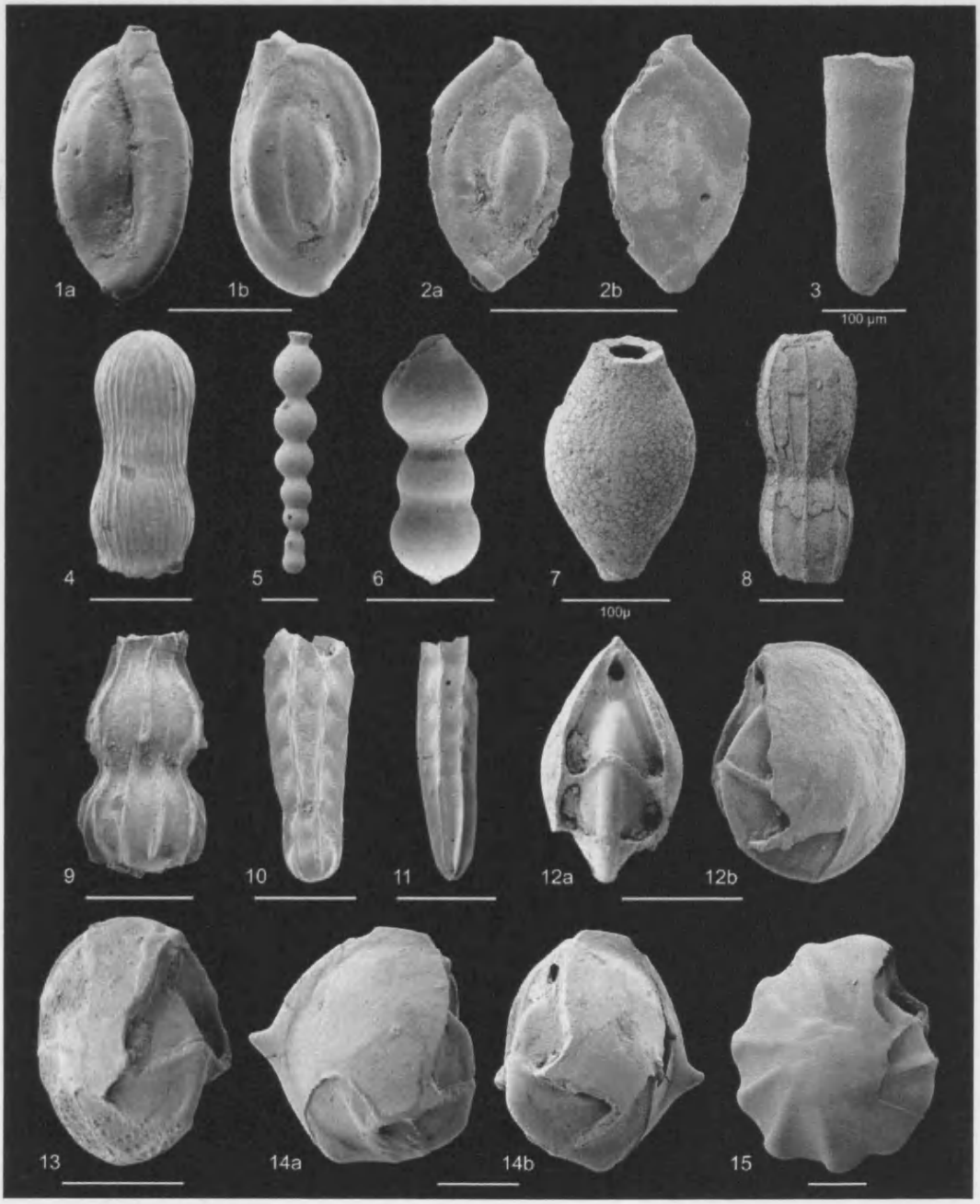


Plate 14. 1. *Sigmoilinella elliptica*, 3140m **2.** *Sigmoilinella tenuis*, 2940m **3.** *Chrysalogonium lanceoleum*, 2940m **4.** *Chrysalogonium* sp.1, 2890m **5.** *Nodosaria anomala*, 3180m **6.** *Nodosaria glandulinoides*, 3070m **7.** *Nodosaria pyrula*, 3050m **8.** *Nodosaria* sp., 3110m **9.** *Amphimorphina* aff. *stainforthi*, 2840m **10.** *Amphimorphina stainforthi*, 2910m **11.** *Amphimorphina stainforthi*, 3160m **12.** *Lenticulina americana*, 2920m **13.** *Lenticulina americana*, 3100m **14.** *Lenticulina calcar*, 2890m **15.** *Lenticulina* aff. *multinodosa*, 3130m. Scale bar = 200 µm. All specimens from well Plutao-1. All specimens from well Plutao-1.

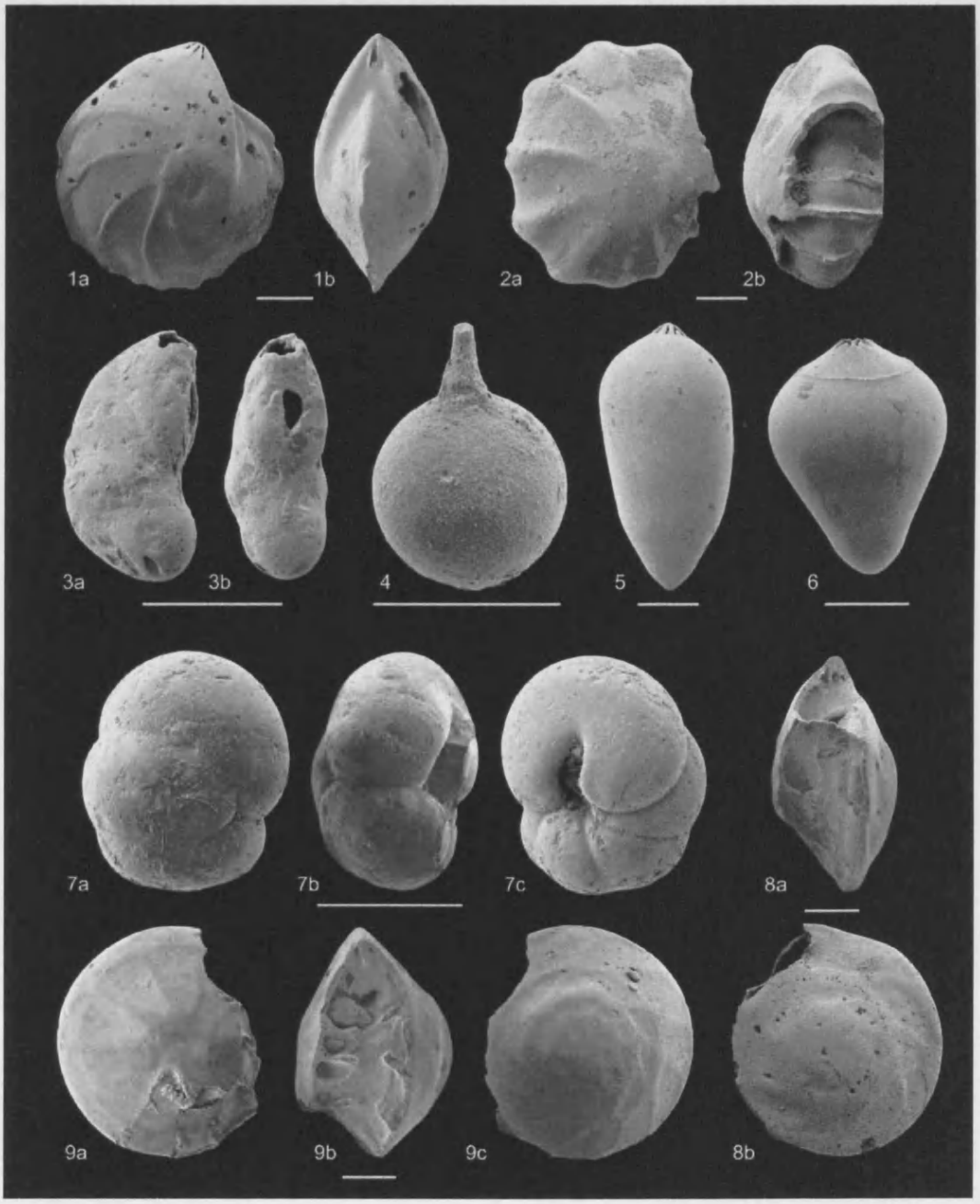


Plate 15. 1. *Lenticulina formosa*, 3130m **2.** *Lenticulina* aff. *multinodosa*, 3050m **3.** *Saracenaria* sp., 3200m **4.** *Pygmaeoseistron* sp., 2900m **5.** *Glandulina ovula*, 2840m **6.** *Glandulina ovula*, 2890m **7.** *Ceratobulimina alazanensis*, 3170m **8.** *Hoeglundina elegans*, 3230m **9.** *Hoeglundina elegans*, 3120m. Scale bar = 200 µm. All specimens from well Plutao-1.

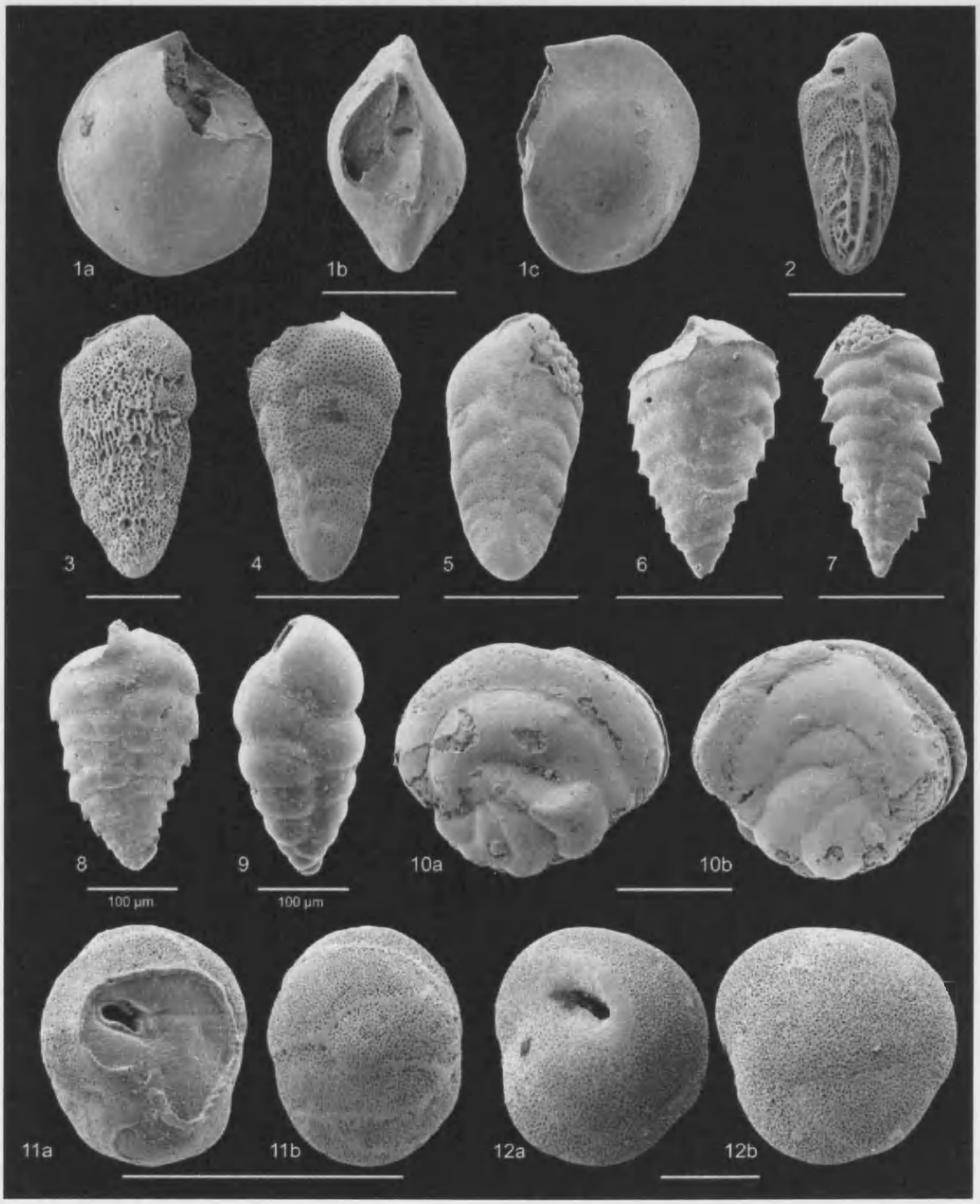


Plate 16. 1. *Hoeglundina elegans*, 3040m **2.** *Bolivina multicostata*, 3110m **3.** *Bolivina tenuisstriata*, 3070m **4.** *Brizalina alazanensis*, 2890m **5.** *Brizalina alazanensis*, 2840m **6.** *Brizalina* cf. *barbata*, 2840m **7.** *Brizalina* cf. *barbata*, 2840m **8.** *Brizalina* cf. *barbata*, 2840m **9.** *Brizalina* aff. *inflata*, 2840m **10.** *Cassidulinella pliocenica*, 2890m **11.** *Globocassidulina punctata*, 3190m **12.** *Globocassidulina punctata*, 3050m. Scale bar = 200 µm. All specimens from well Plutao-1.

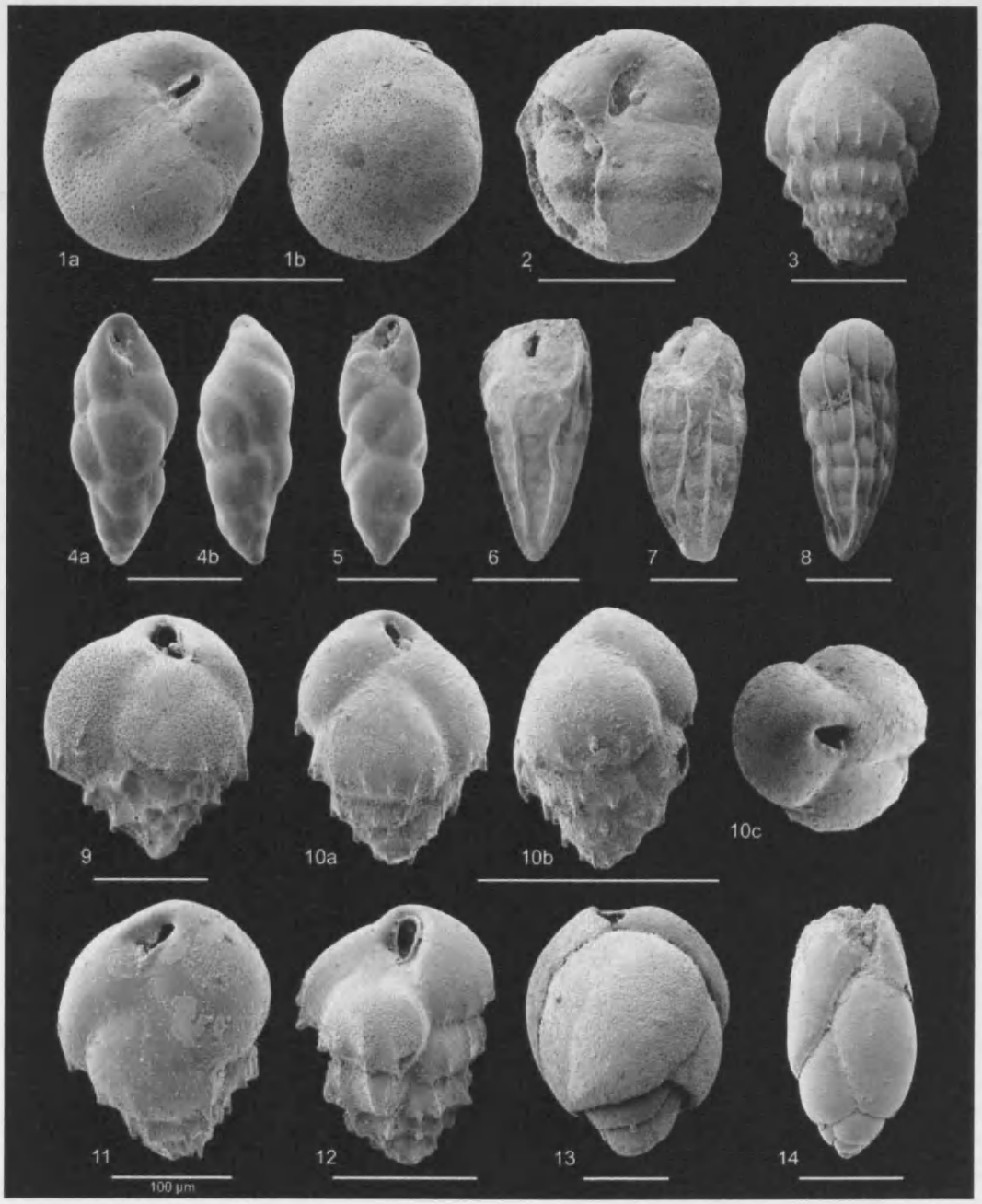


Plate 17. 1. *Globocassidulina subglobosa*, 2940m **2.** *Globocassidulina subglobosa*, 2810m **3.** *Bulimina buchiana*, 3050m **4.** *Bulimina elongata*, 2940m **5.** *Bulimina elongata*, 2940m **6.** *Bulimina sculptilis*, 3060m **7.** *Bulimina falconensis*, 2840m **8.** *Bulimina falconensis*, 3110m **9.** *Bulimina macilenta*, 3050m **10.** *Bulimina marginata*, 2840m **11.** *Bulimina marginata*, 2840m **12.** *Bulimina mexicana*, 3070m **13.** *Bulimina* sp., 3060m **14.** *Praeglobobulimina ovata*, 2900m. Scale bar = 200 µm. All specimens from well Plutao-1.

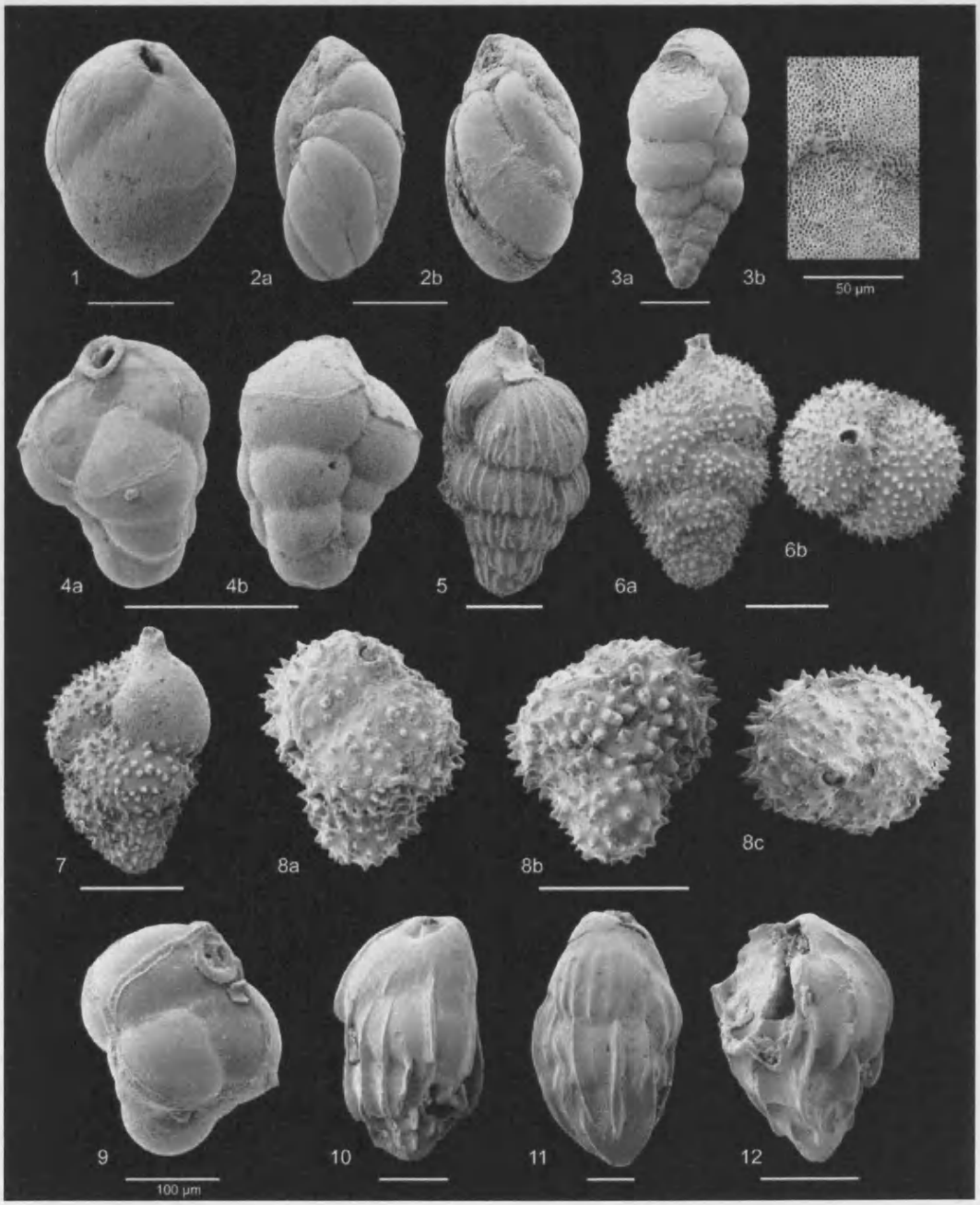


Plate 18. 1. *Praeglobobulimina socialis*, 3280m **2.** *Buliminella* sp.1, 2890m **3.** *Uvigerina* aff. *carapitana*, 2890m **4.** *Uvigerina* aff. *carapitana*, 2840m **5.** *Uvigerina spinulosa*, 3050m **6.** *Uvigerina hispida*, 2920m **7.** *Uvigerina hispida*, 3090m **8.** *Uvigerina hispida*, 2840m **9.** *Uvigerina* aff. *carapitana*, 2840m **10.** *Uvigerina macrocarinata*, 3100m **11.** *Uvigerina macrocarinata*, 2920m **12.** *Uvigerina macrocarinata*, 3070m. Scale bar = 200 µm. All specimens from well Plutao-1.

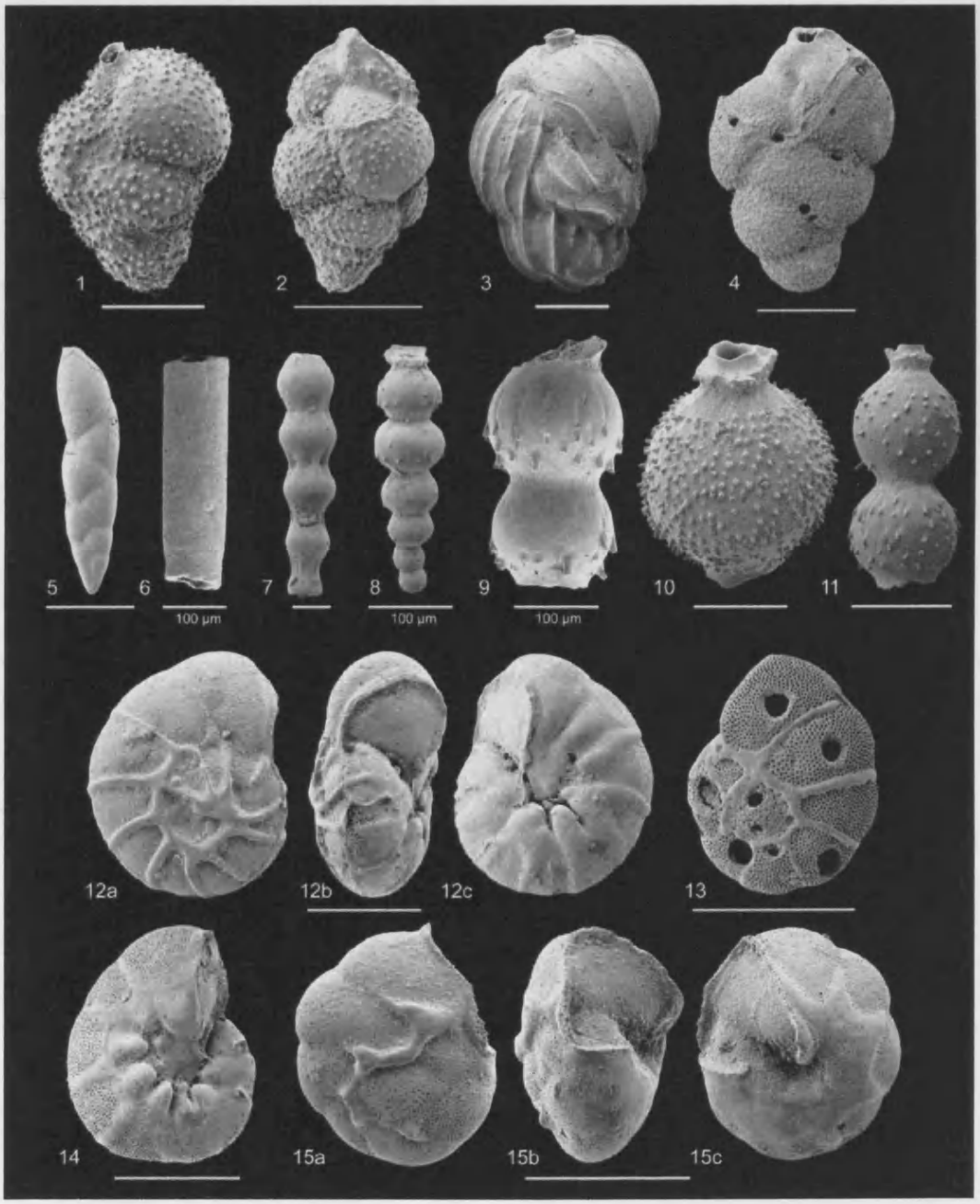


Plate 19. 1. *Uvigerina mantaensis*, 3420m **2.** *Uvigerina mantaensis*, 3070m **3.** *Uvigerina* aff. *mediterranea*, 3130m **4.** *Uvigerina proboscidea*, 3050m **5.** *Fursekoina bramlettei*, 3160m **6.** *Neugeborina longiscata*, 3050m **7.** *Siphonodosaria* aff. *abyssorum*, 2920m **8.** *Stilostomella adolphina*, 3050m **9.** *Stilostomella subspinosa*, 2840m **10.** *Stilostomella subspinosa*, 3190m **11.** *Stilostomella subspinosa*, 3070m **12.** *Valvulineria pseudotumeyensis*, 2890m **13.** *Valvulineria pseudotumeyensis*, 2810m **14.** *Valvulineria pseudotumeyensis*, 2810m **15.** *Valvulineria pseudotumeyensis*, 2980m. Scale bar = 200 µm. All specimens from well Plutao-1.

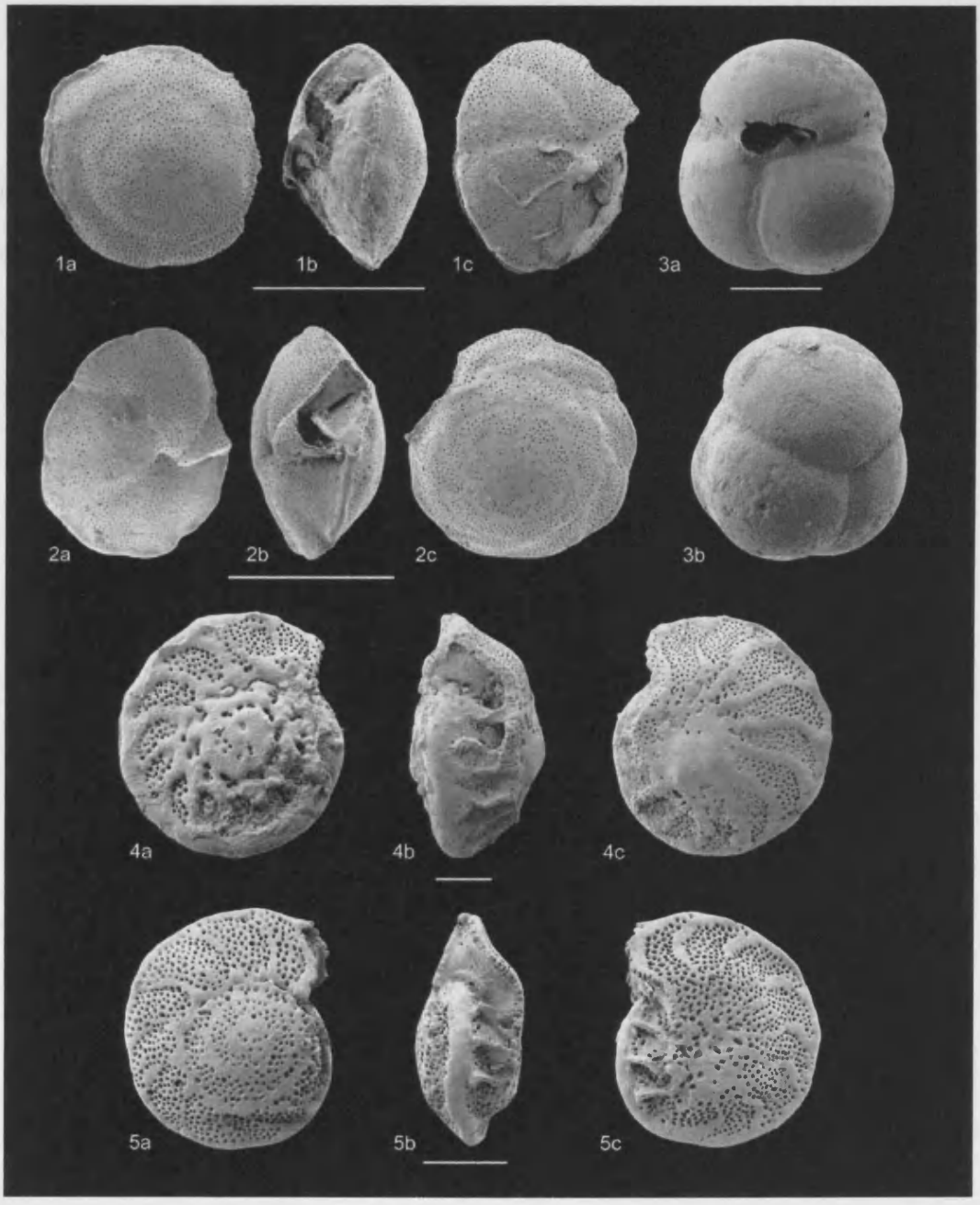


Plate 20. 1. *Neoeponides campester*, 2890m **2.** *Neoeponides campester*, 2910m **3.** *Sphaeroidina bulloides*, 3070m **4.** *Cibicidoides crebbsi*, 2890m **5.** *Cibicidoides crebbsi*, 3050m. Scale bar = 200 μm. All specimens from well Plutao-1.

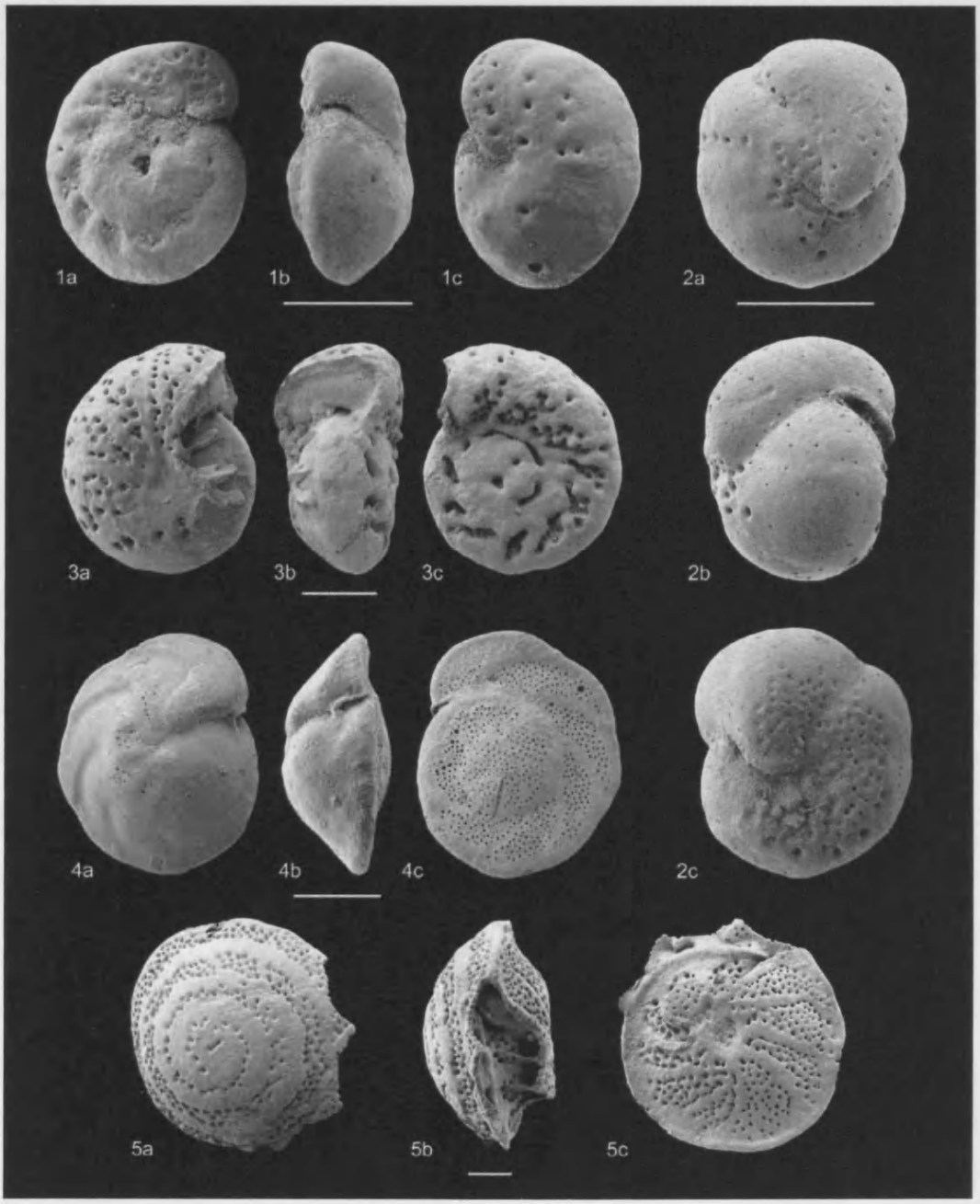


Plate 21. 1. *Cibicidoides dohmi*, 3120m **2.** *Cibicidoides grimsdalei*, 2900m **3.** *Cibicidoides dohmi*, 3210m **4.** *Cibicidoides guazumalensis*, 3000m **5.** *Cibicidoides havanensis*, 2900m. Scale bar = 200 μm. All specimens from well Plutao-1.

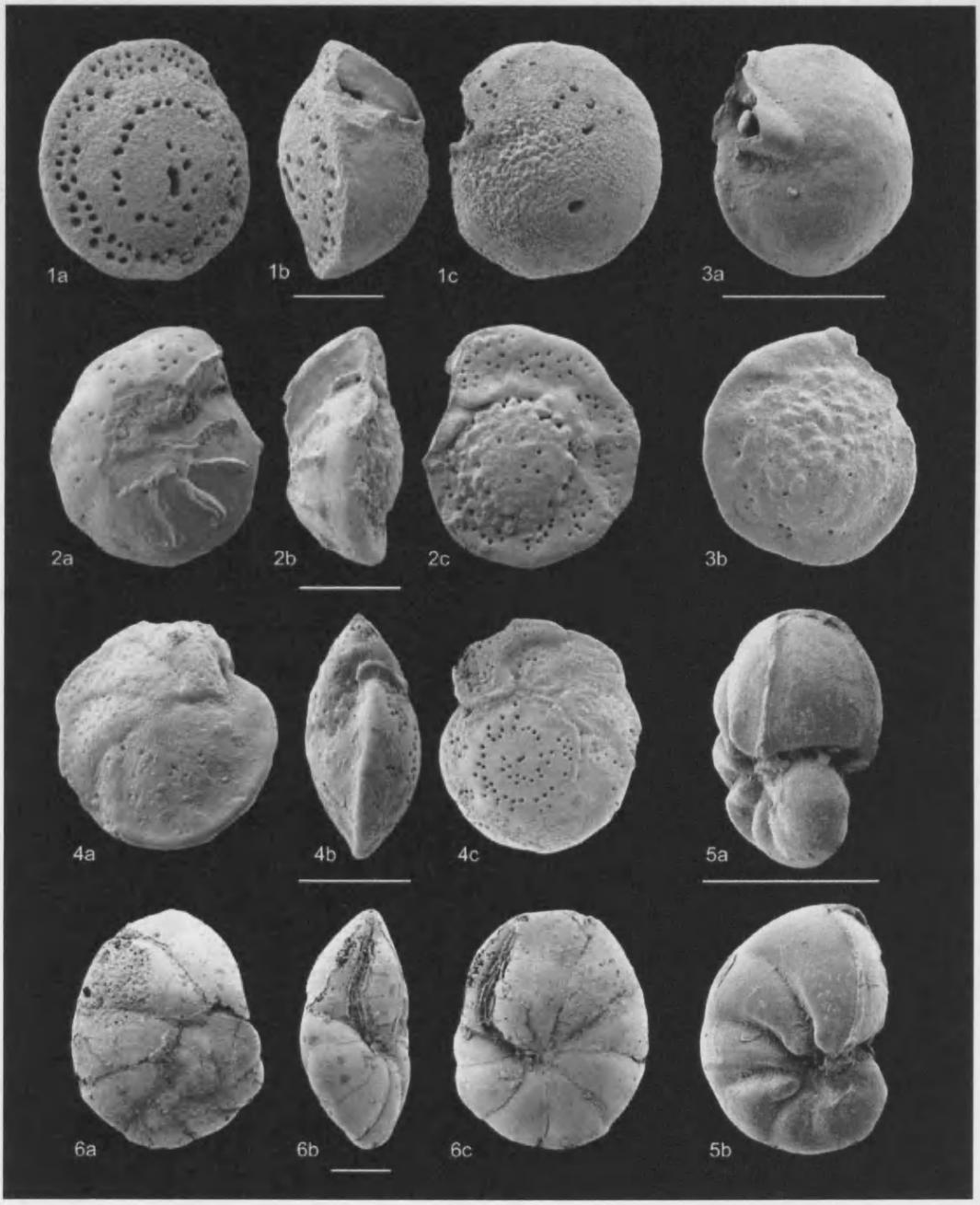


Plate 22. 1. *Cibicidoides havanensis*, 3110m **2.** *Cibicidoides mundulus*, 3200m **3.** *Cibicidoides mundulus*, 2900m **4.** *Cibicidoides pachyderma*, 3050m **5.** *Nonion* sp.1, 2840m **6.** *Megastomella africana*, 2840m. Scale bar = 200 μm. All specimens from well Plutao-1.

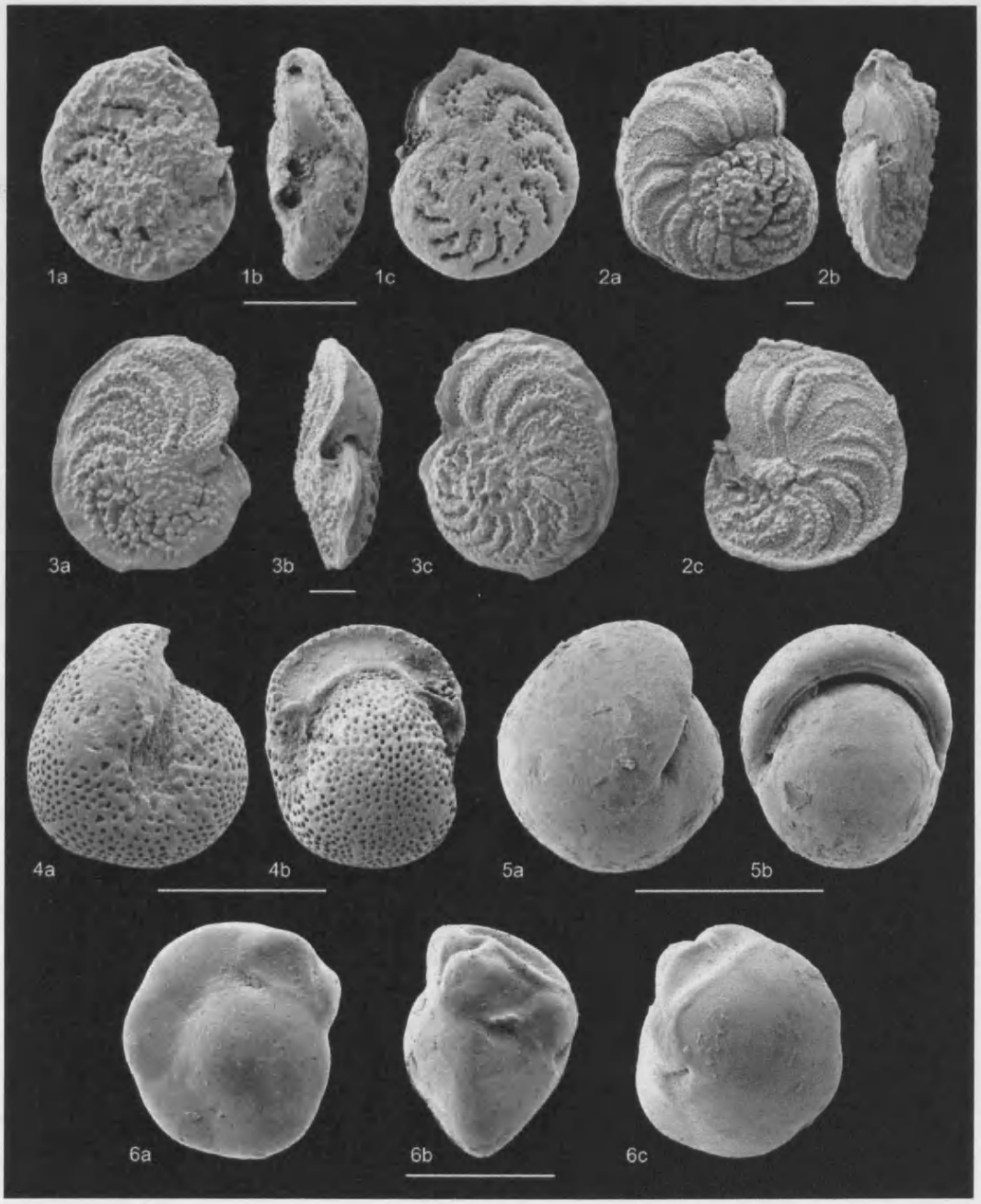


Plate 23. 1. *Planulina renzi*, 2840m **2.** *Planulina renzi*, 3120m **3.** *Planulina renzi*, 3200m **4.** *Melonis pompilioides*, 2940m **5.** *Pullenia bulloides*, 2980m **6.** *Oridorsalis umbonatus*, 3410m. Scale bar = 200 μm. All specimens from well Plutao-1.

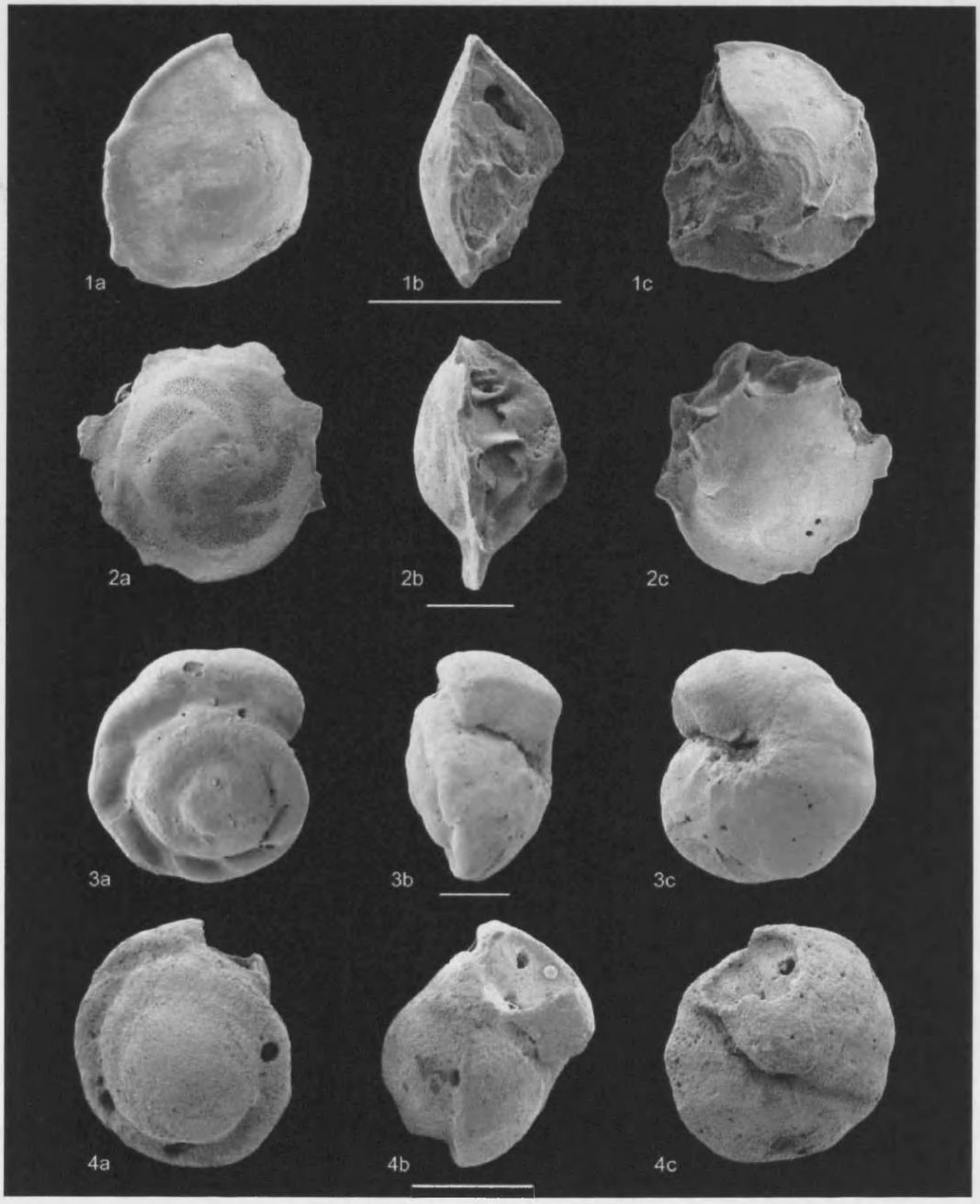


Plate 24. 1 *Oridorsalis umbonatus*, 3060m **2.** *Oridorsalis umbonatus*, 2920m **3.** *Gyroidinoides altiformis*, 3050m **4.** *Gyroidinoides altispira*, 3190m. Scale bar = 200 μm. All specimens from well Plutao-1.

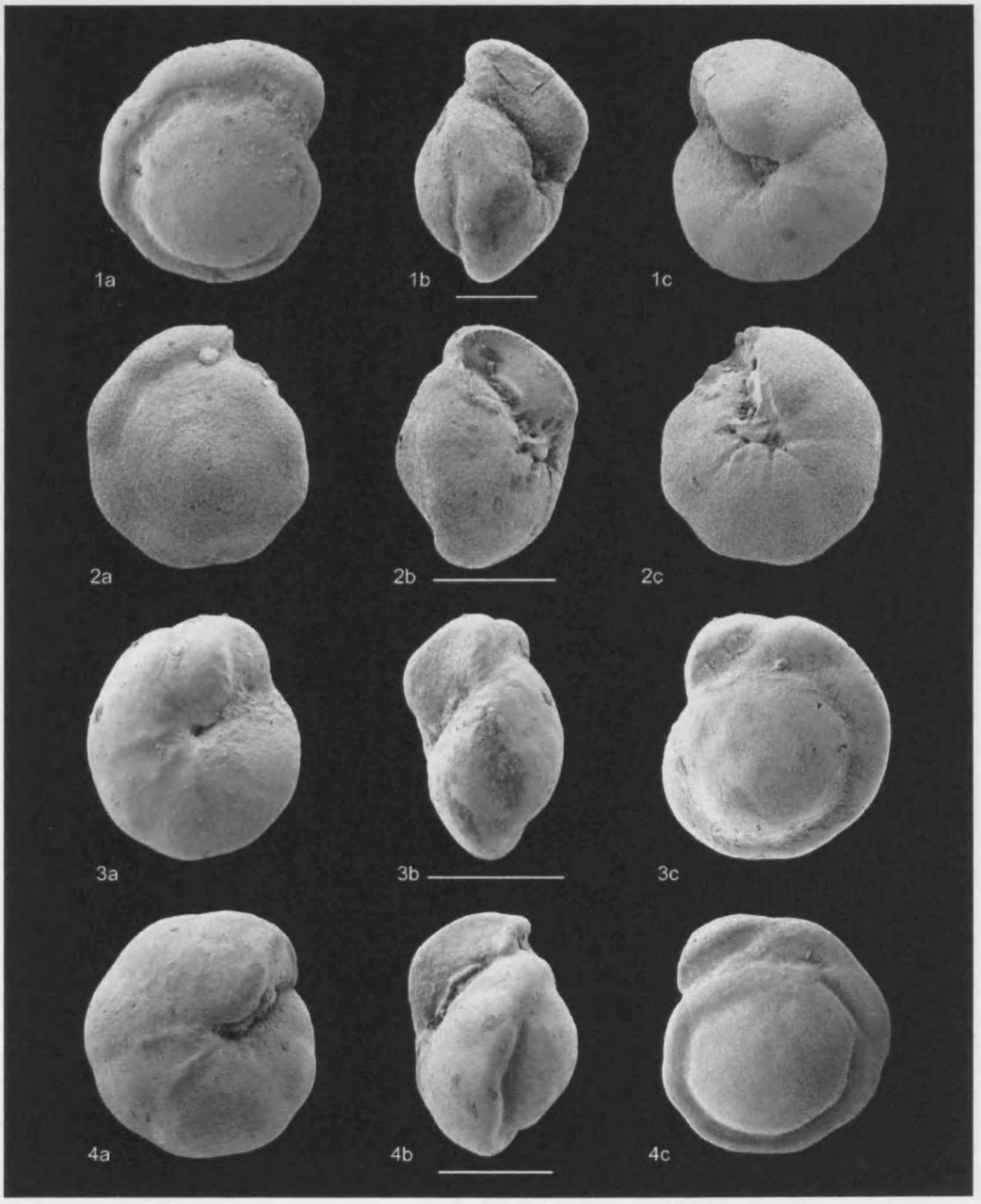


Plate 25. 1. *Gyroidinoides soldanii*, 2900m **2.** *Gyroidinoides soldanii*, 2900m **3.** *Gyroidina orbicularis*, 2810m **4.** *Gyroidina orbicularis*, 3080m. Scale bar = 200 µm. All specimens from well Plutao-1.

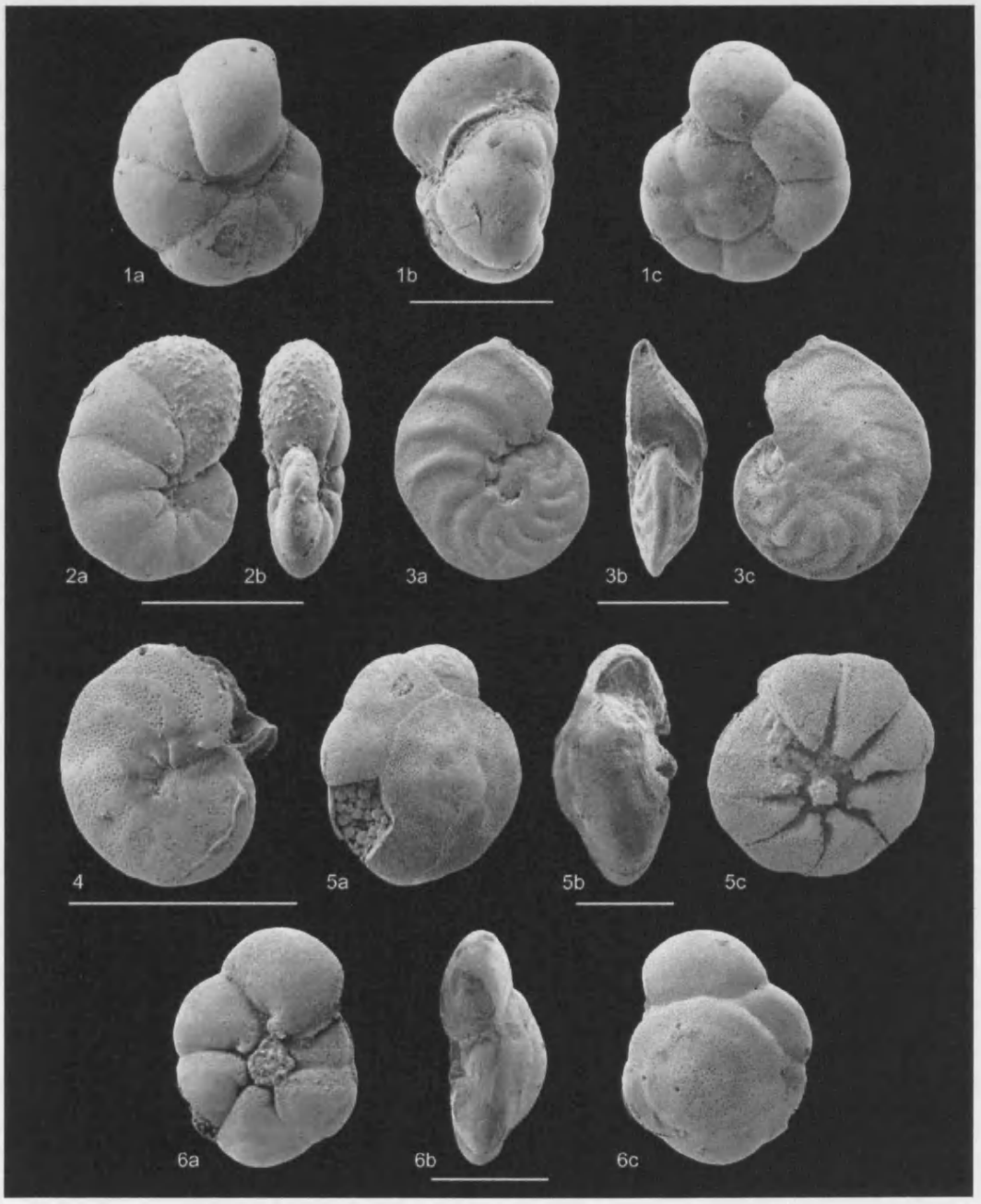


Plate 26. 1. *Gyroidina umbonata*, 2840m **2.** *Hanzawaia* sp.1, 2900m **3.** *Hanzawaia mantaensis*, 3050m **4.** *Hanzawaia mantaensis*, 2910m **5.** *Ammonia* cf. *parkinsoniana*, 3130m **6.** *Ammonia* sp., 3130m. Scale bar = 200 μm. All specimens from well Plutao-1.

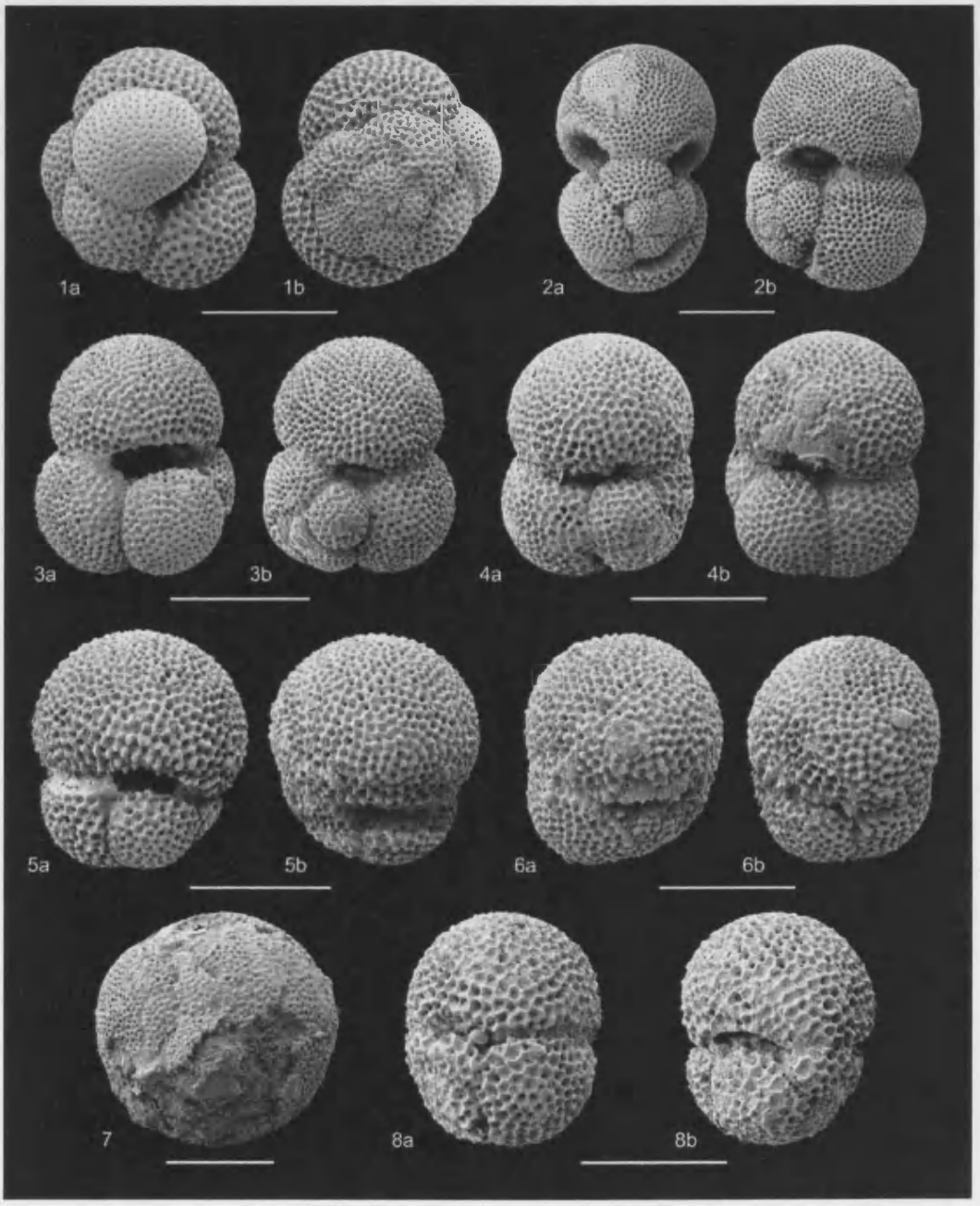


Plate 27. 1. *Catapsydrax unicavus*, 3210m **2.** *Globigerinoides sacculifer*, 3120m **3.** *Globigerinoides immaturus*, 3010m **4.** *Globigerinoides trilobus*, 2890m **5.** *Globigerinoides bisphericus*, 2840m **6.** *Praeorbulina sicana*, 3040m **7.** *Praeorbulina glomerosa glomerosa*, 2890m **8.** *Globigerinoides bisphericus*, 2890m. Scale bar = 200 μm. All specimens from well Plutao-1.

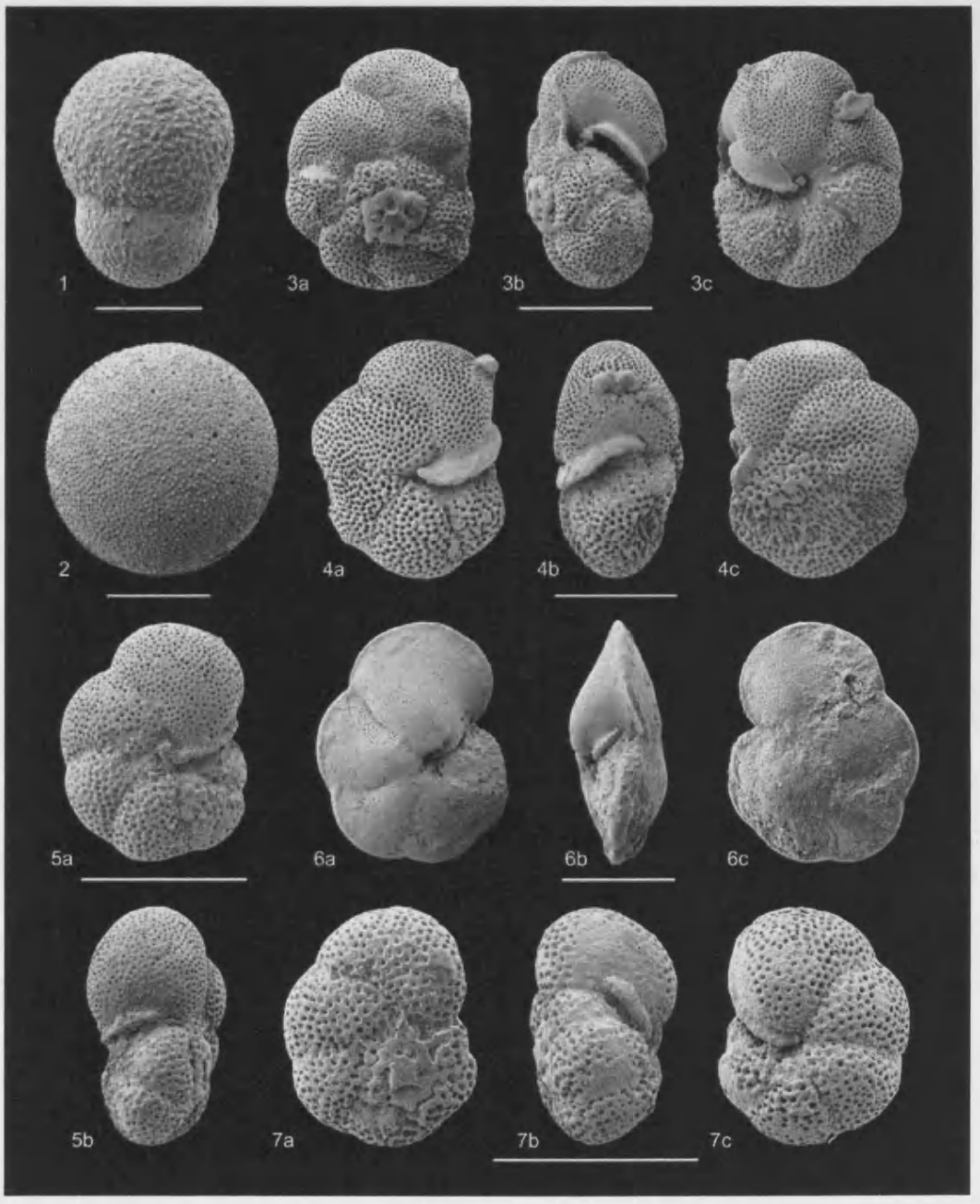


Plate 28. 1. *Orbulina bilobata*, 2760m **2.** *Orbulina universa*, 2800m **3.** *Globorotalia peripheroronda*, 2920m **4.** *Globorotalia peripheroronda*, 3180m **5.** *Globorotalia mayeri*, 3100m **6.** *Globorotalia praemenardii*, 2930m **7.** *Globorotalia* sp., 2840m. Scale bar = 200 μm. All specimens from well Plutao-1.

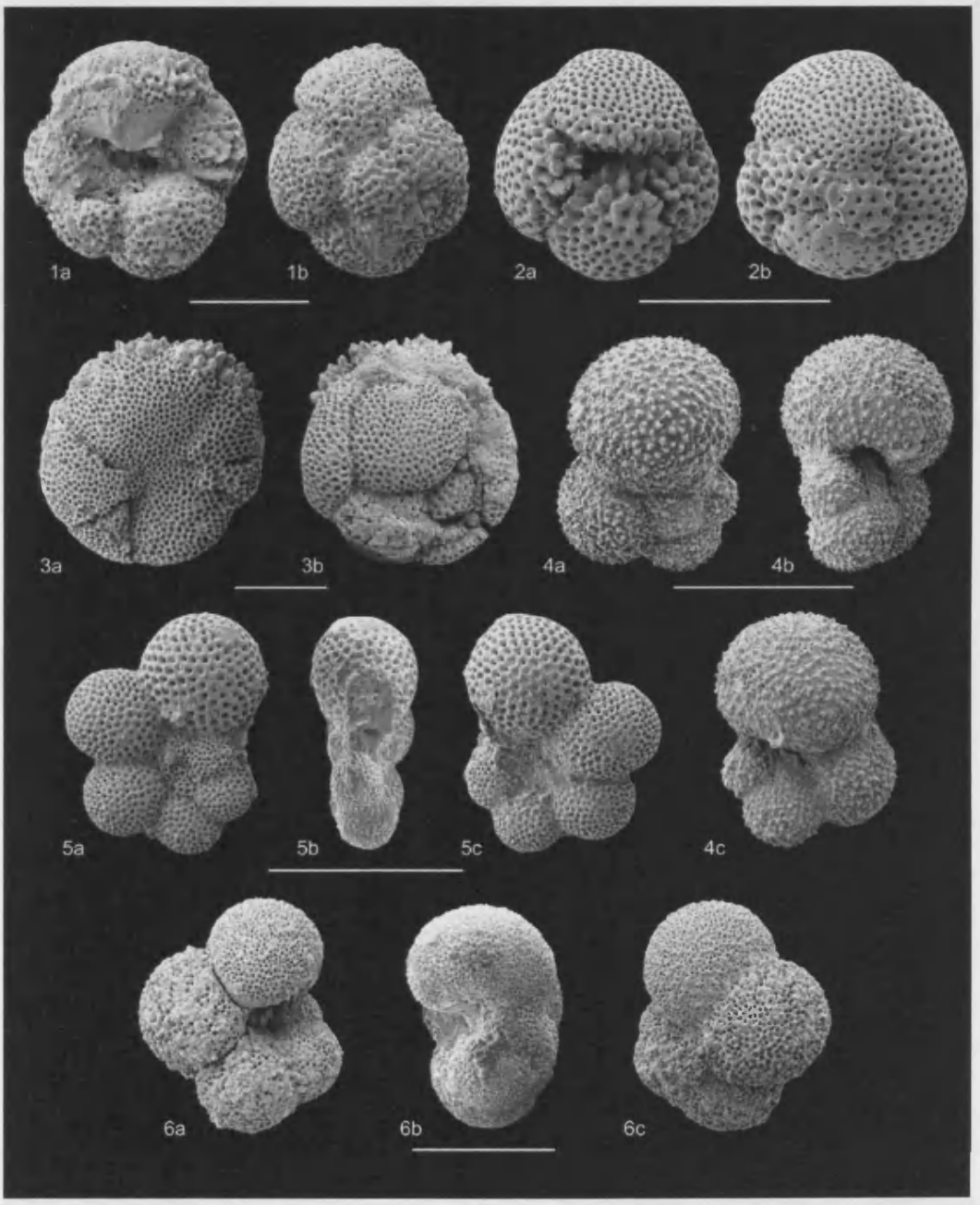


Plate 29. 1. *Globoquadrina dehiscens*, 3060m **2.** *Globoquadrina venezuelana*, 2910m **3.** *Dentoglobigerina altispira*, 2810m **4.** *Globigerinella obesa*, 2890m **5.** *Globorotaloides hexagona*, 3080m **6.** *Globigerinella praesiphonifera*, 3120m. Scale bar = 200 μm. All specimens from well Plutao-1.

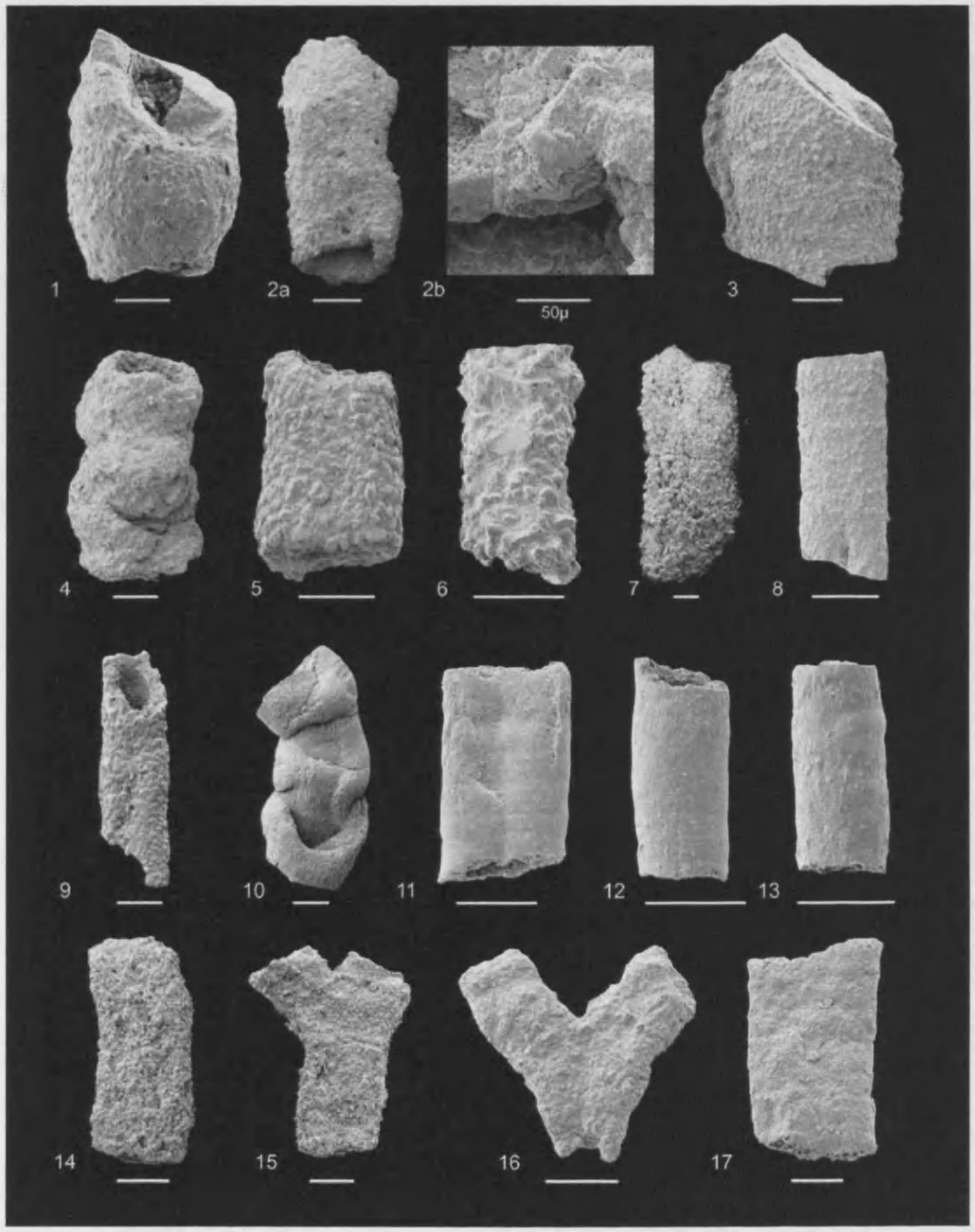


Plate 30. **1.** *Rhabdammina linearis*, 3880m. **2.** *Rhabdammina* sp., 4170m. **3.** *Rhabdammina* sp., 4100m. **4.** *Rhabdammina* sp., 4100m. **5.** *Rhabdammina* sp., 4100m. **6.** *Rhabdammina* sp., 4100m. **7.** *Rhabdammina* sp., 3820m. **8.** *Rhabdammina* sp., 3800m. **9.** *Rhabdammina* sp., 2840m. **10.** *Rhabdammina* sp., 3850m. **11.** *Bathysiphon* sp., 3780m. **12.** *Bathysiphon* sp., 3900m. **13.** *Bathysiphon* sp., 3900m. **14.** *Nothia* aff. *excelsa*, 3820m. **15.** *Nothia* aff. *excelsa*, 3820m. **16.** *Nothia* aff. *excelsa*, 4180m. **17.** *Nothia latissima*, 3750m. All scale bars 200µm unless otherwise indicated. All specimens from well Plutao-1.

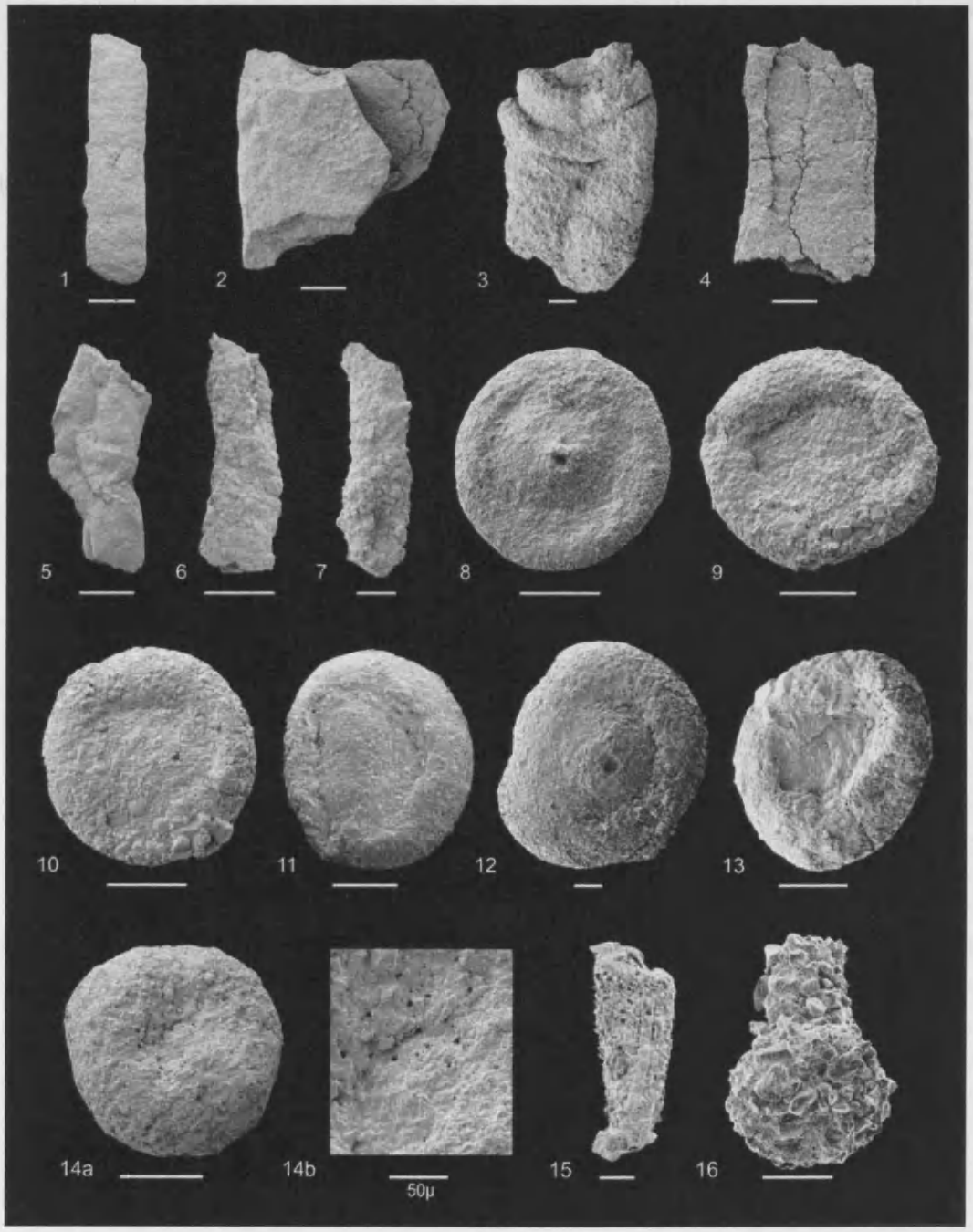


Plate 31. **1.** *Nothia latissima*, 3750m. **2.** *Nothia robusta*, 3810m. **3.** *Nothia robusta*, 3740m. **4.** *Nothia* sp., 3800m. **5.** *Rhizammina* sp., 3900m. **6.** *Rhizammina* sp., 3900m. **7.** *Rhizammina* sp., 4100m. **8.** *Placentammina placenta*, 3820m. **9.** *Saccammina* cf. *spherica*, 3830m. **10.** *Saccammina* cf. *spherica*, 3840m. **11.** *Saccammina* sp.1, 3810m. **12.** *Saccammina* sp.3, 3940m. **13.** *Psammosphaera* sp.1, 3800m. **14.** *Psammosphaera* cf. *fusca*, 3850m **15.** *Jaculella* sp.1 with attached *Ammolagena* sp., 4010m. **16.** *Hyperammina elongata*, 4010m. All scale bars 200µm unless otherwise indicated. All specimens from well Plutao-1.

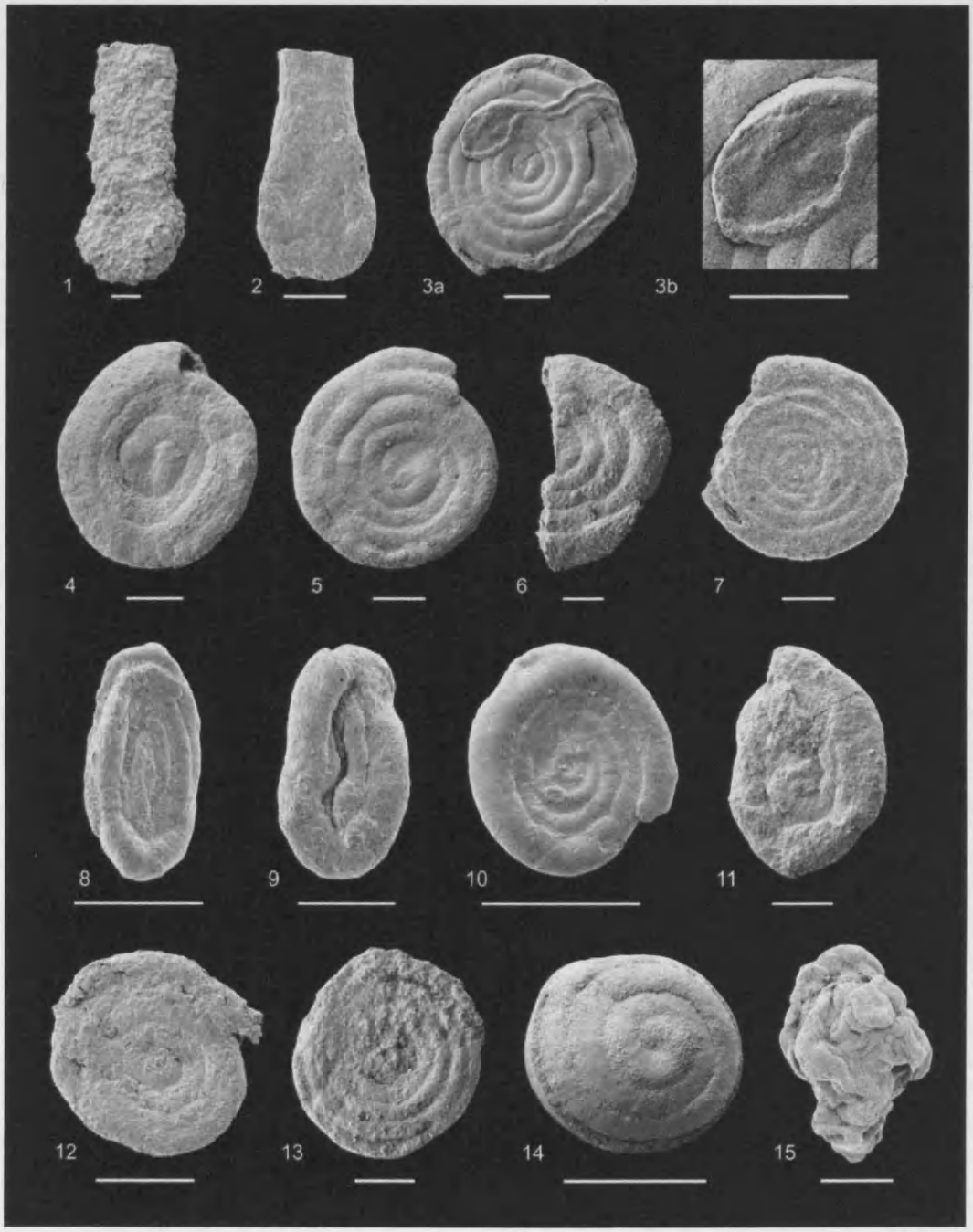


Plate 32. 1. *Hyperammina* sp., 4250m. **2.** *Hyperammina* sp., 4170m. **3.** *Ammodiscus cretaceus* with attached *Ammolagena clavata*, 3830m. **4.** *Ammodiscus latus*, 3840m. **5.** *Ammodiscus latus*, 3840m. **6.** *Ammodiscus latus*, 3860m. **7.** *Ammodiscus tenuissimus*, 4060m. **8.** *Ammodiscus* sp.1, 3810m. **9.** *Ammodiscus* aff. *peruvianus*, 3850m. **10.** *Ammodiscus* sp.2, 3840m. **11.** *Ammodiscus* sp.2, 3820m. **12.** *Ammodiscus* sp., 3810m. **13.** *Ammodiscus* sp., 3840m. **14.** *Glomospira charoides*, 2900m. **15.** *Glomospira glomerata*, 3820m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

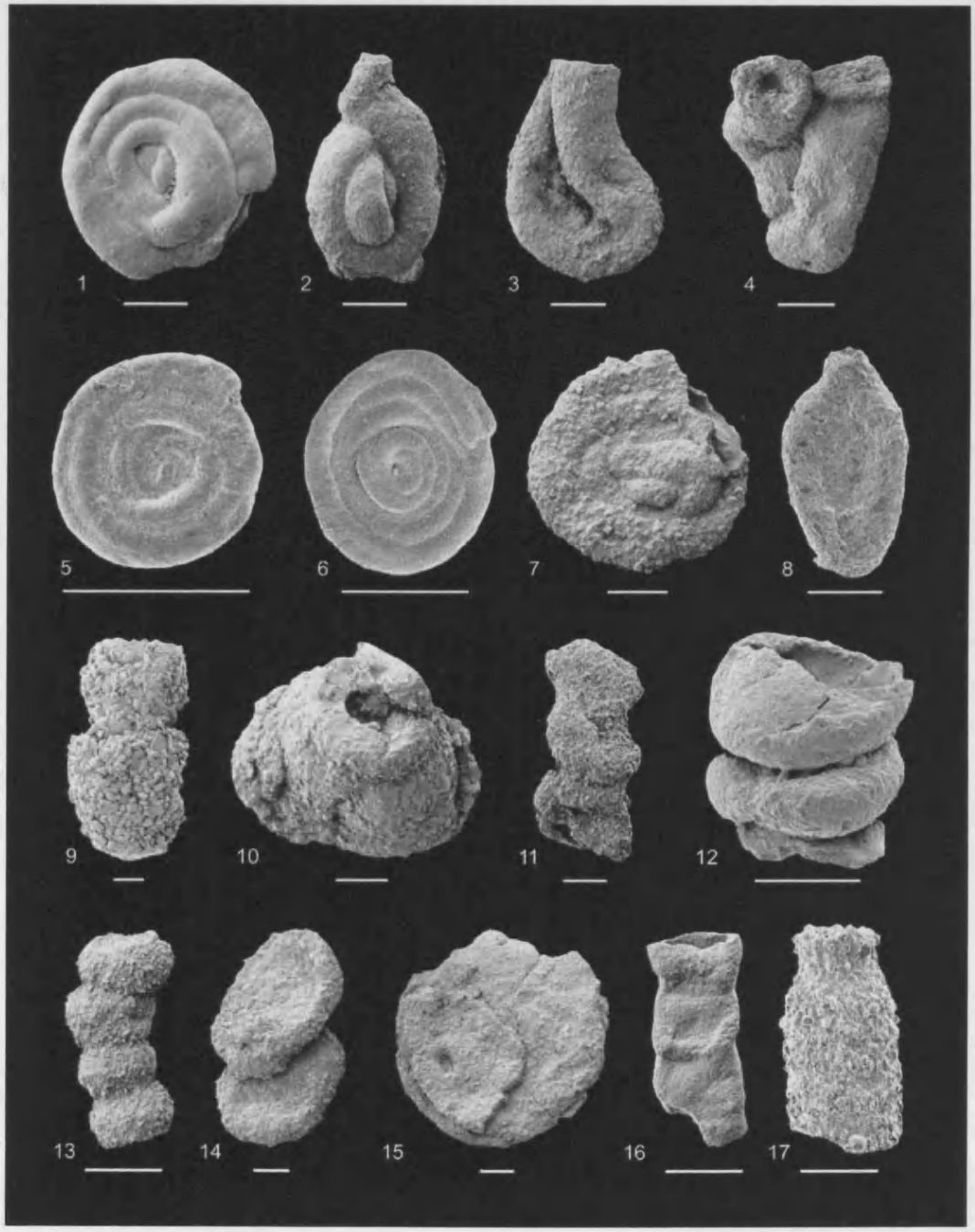


Plate 33. **1.** *Glomospira gordialis*, 3860m. **2.** *Glomospira irregularis*, 3860m. **3.** *Glomospira* aff. *irregularis*, 3840m. **4.** *Glomospira* aff. *irregularis*, 3840m. **5.** *Glomospira* sp.1, 3810m. **6.** *Glomospira* sp.1, 3810m. **7.** *Glomospira* sp.2, 3850m. **8.** *Caudammina* aff. *ovuloides*, 4150m. **9.** *Hormosinella carpenteri*, 3900m. **10.** *Reophanus berggreni*, 3850m. **11.** *Subreophax pseudoscalaris*, 3910m. **12.** *Subreophax scalaris*, 4170m. **13.** *Subreophax scalaris*, 3860m. **14.** *Aschemocella grandis*, 3960m. **15.** *Aschemocella grandis*, 4130m. **16.** *Aschemocella* sp., 3830m. **17.** *Kalamopsis* sp., 4030m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

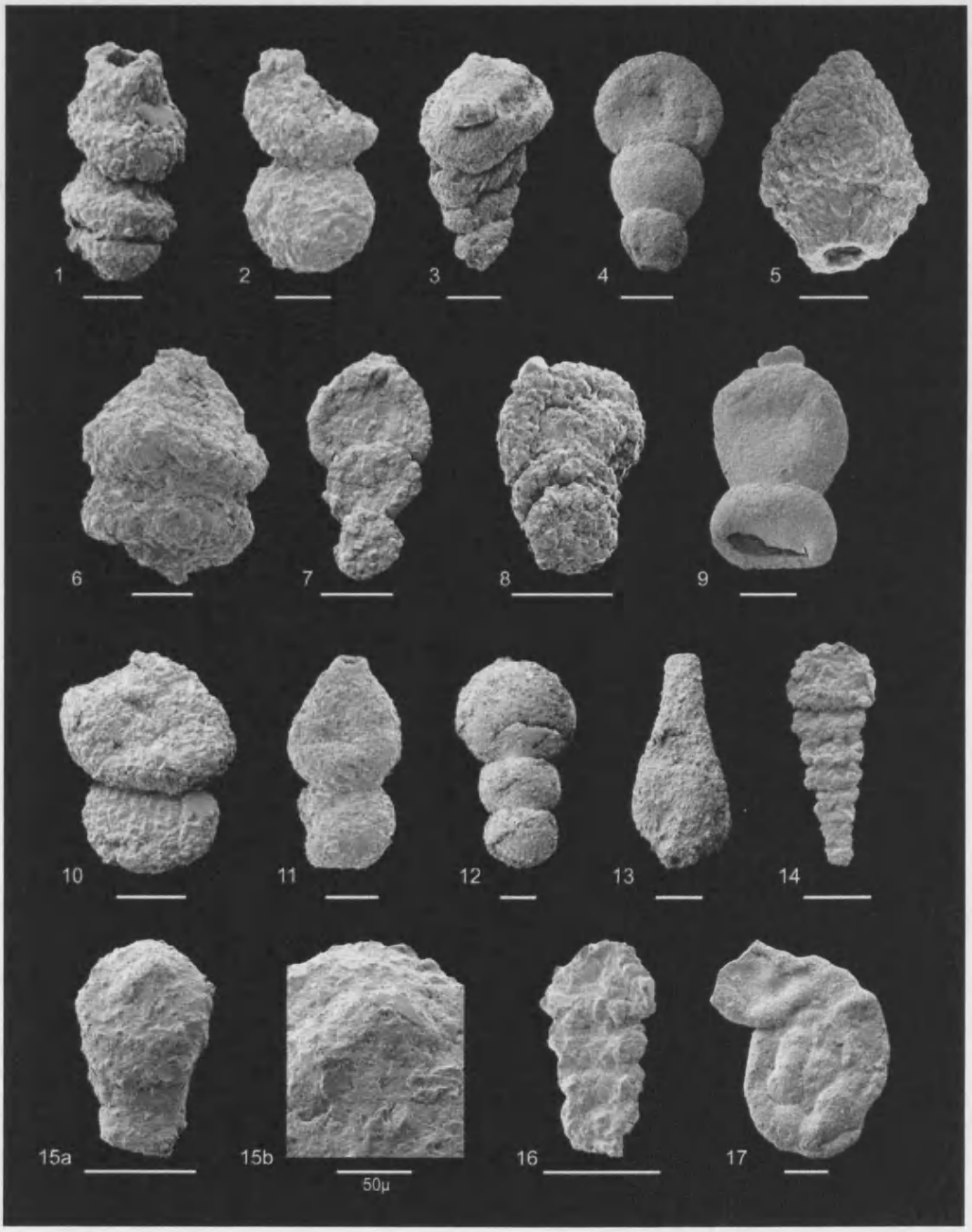


Plate 34. **1.** *Hormosinelloides guttifer*, 3840m. **2.** *Reophax duplex*, 4000m. **3.** *Reophax pilulifer*, 3920m. **4.** *Reophax pilulifer*, 3840m. **5.** *Reophax pyrifer*, 4120m. **6.** *Reophax pyrifer*, 3810m. **7.** *Reophax* sp.1, 3830m. **8.** *Reophax* sp.1, 3750m. **9.** *Reophax* sp.2, 3810m. **10.** *Reophax* sp., 3850m. **11.** *Hormosina glabra*, 3890m. **12.** *Hormosina globulifera*, 2810m. **13.** *Pseudonodosinella elongata*, 3820m. **14.** *Scherochorella congoensis*, 4040m. **15.** *Scherochorella congoensis*, 4020m. **16.** *Scherochorella congoensis*, 4040m. **17.** *Lituotuba lituiformis*, 3860m. All scale bars 200µm unless otherwise indicated. All specimens from well Plutao-1.

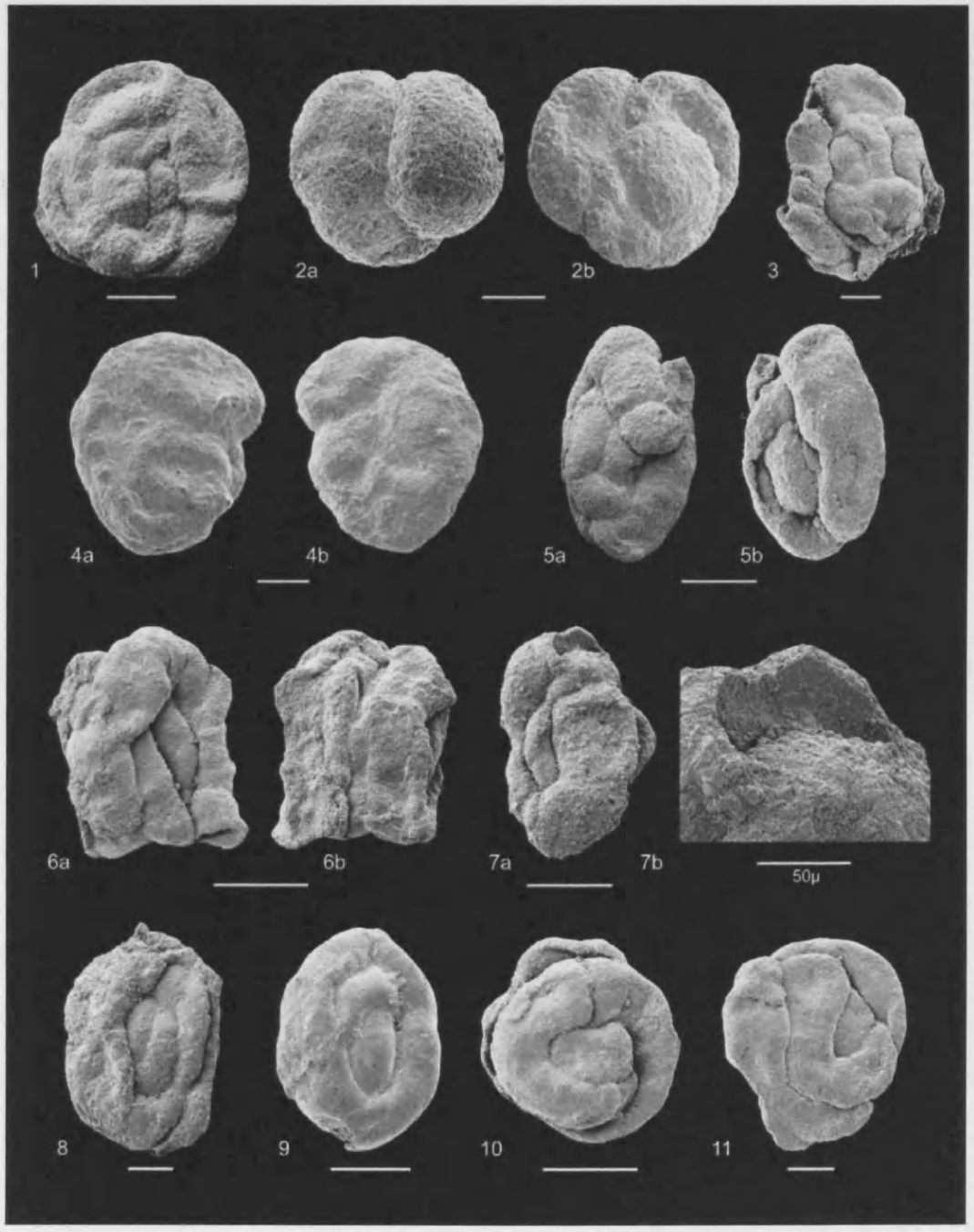


Plate. 35. 1. *Lituotuba lituiformis*, 3860m. **2.** *Paratrochamminoides* ex gr. *challengeri*, 4060m. **3.** *Paratrochamminoides* aff. *deflexiformis*, 4030m. **4.** *Paratrochamminoides* aff. *deflexiformis*, 4240m. **5.** *Paratrochamminoides gorayskiformis*, 3850m. **6.** *Paratrochamminoides gorayskiformis*, 3830m. **7.** *Paratrochamminoides gorayskiformis*, 3830m. **8.** *Paratrochamminoides gorayskiformis*, 3870m. **9.** *Paratrochamminoides gorayskii*, 3810m. **10.** *Paratrochamminoides olszewskii*, 3800m. **11.** *Paratrochamminoides olszewskii*, 4170m. All scale bars 200µm unless otherwise indicated. All specimens from well Plutao-1.

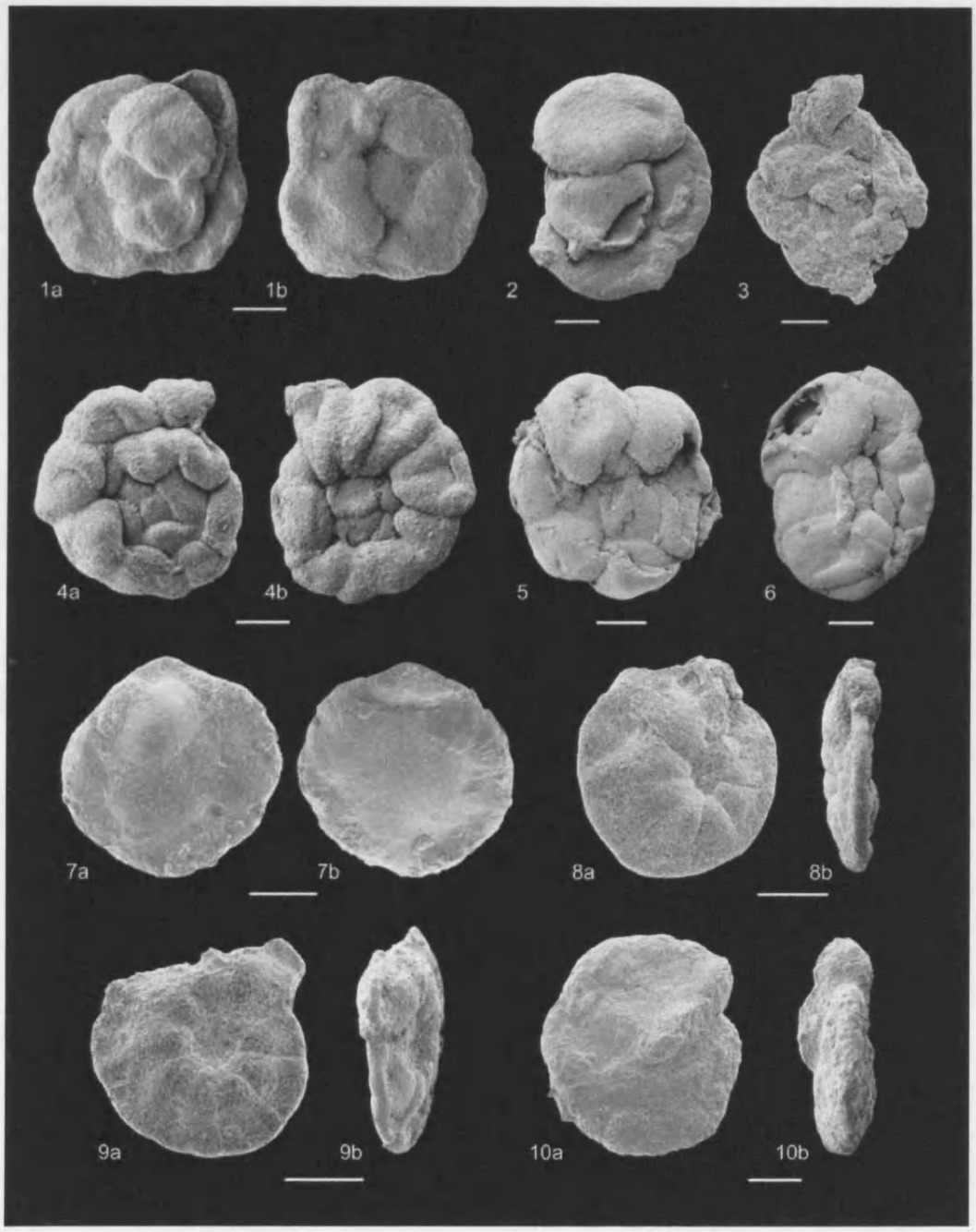


Plate 36. **1.** *Paratrochamminoides* sp.1, 3930m. **2.** *Conglophragmium irregulare*, 3830m. **3.** *Trochamminoides folius*, 3960m. **4.** *Trochamminoides* aff. *proteus*, 3820m. **5.** *Trochamminoides* aff. *proteus*, 3900m. **6.** *Trochamminoides subcoronatus*, 3140m. **7.** *Buzasina* aff. *pacifica*, 4130m. **8.** *Haplophragmoides carinatus*, 4090m. **9.** *Haplophragmoides carinatus*, 4130m. **10.** *Haplophragmoides* aff. *horridus*, 4240m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

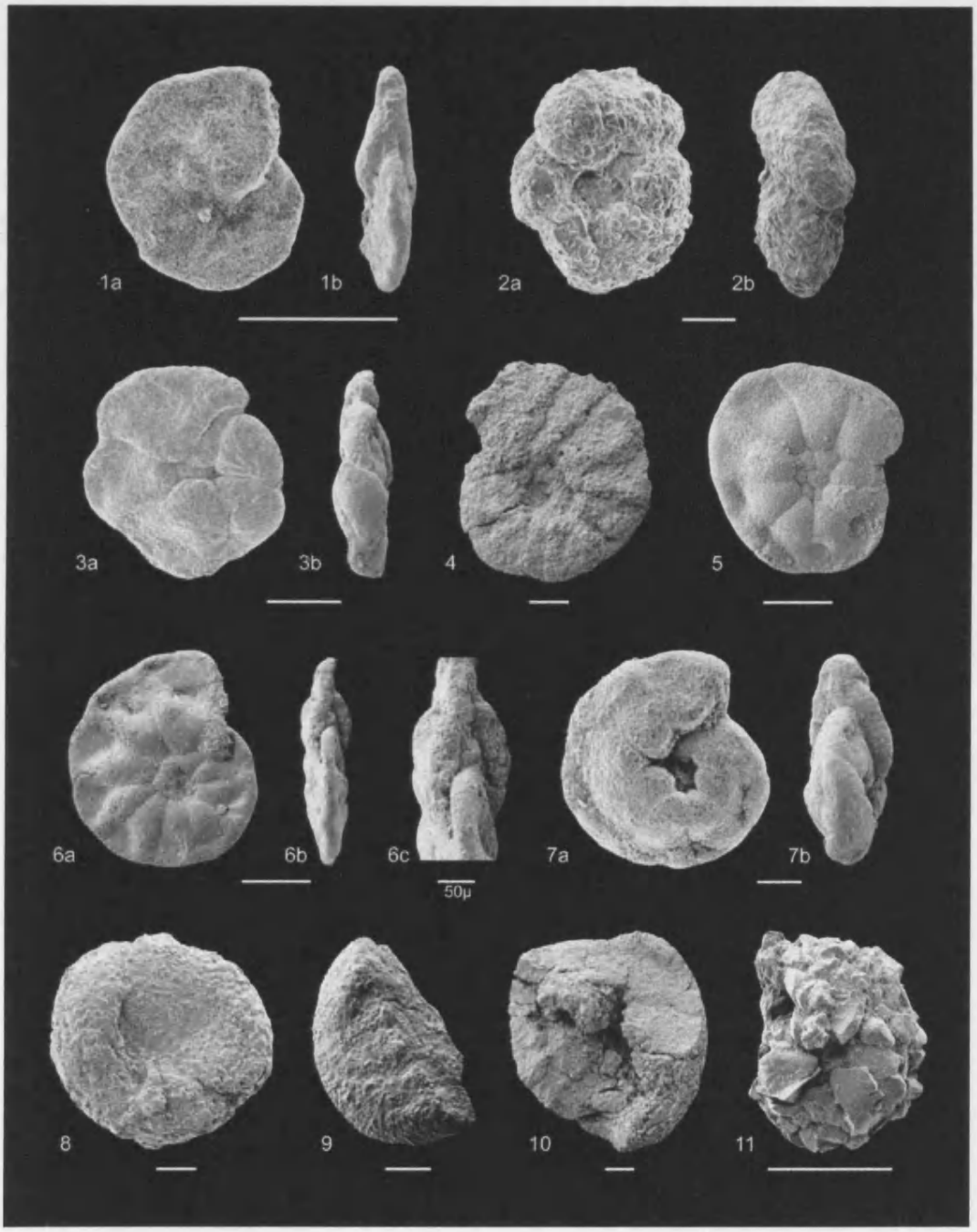


Plate 37. **1.** *Haplophragmoides walteri*, 4020m. **2.** *Haplophragmoides* sp.1, 3990m. **3.** *Haplophragmoides* sp., 3870m. **4.** *Glaphyrammina americana*, 3820m. **5.** *Haplophragmoides nauticus*, 3800m. **6.** *Haplophragmoides nauticus*, 3840m. **7.** *Haplophragmoides* sp.2, 4000m. **8.** *Praesphaerammina* sp.1, 4240m. **9.** *Praesphaerammina* sp.1, 4240m. **10.** *Praesphaerammina* sp.1, 3850m. **11.** *Ammomarginulina* sp., 3850m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

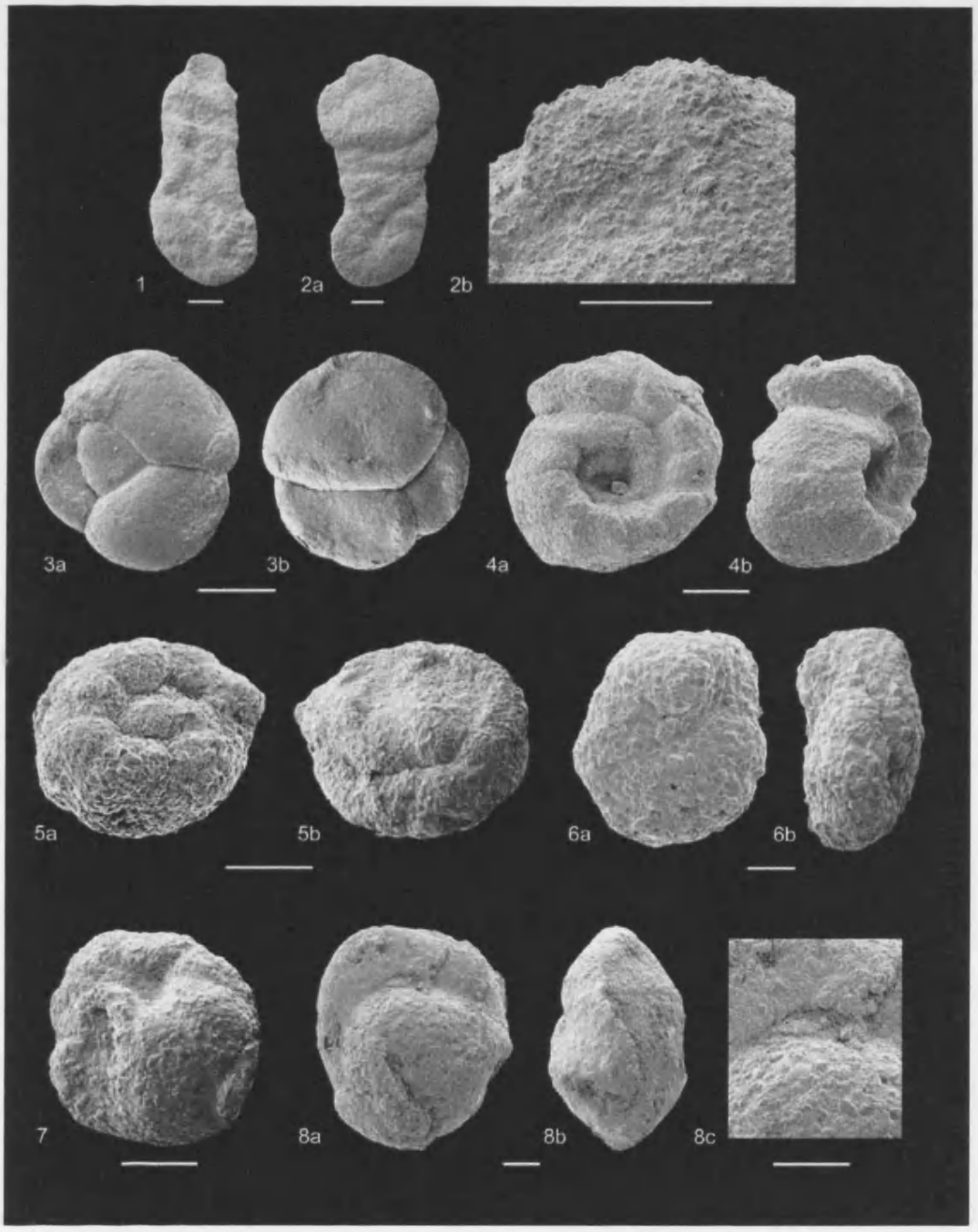


Plate 38. **1.** *Discamminoides* sp.1, 4030m. **2.** *Discamminoides* sp.1, 4030m. **3.** *Ammosphaeroidina pseudopauciloculata*, 3850m. **4.** *Evolutinella rotulata*, 3890m. **5.** *Budashevaella multicamerata*, 3840m. **6.** *Recurvoides* sp.2, 3930m. **7.** *Budashevaella multicamerata*, 3860m. **8.** *Cribrostomoides subglobosus*, 4120m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

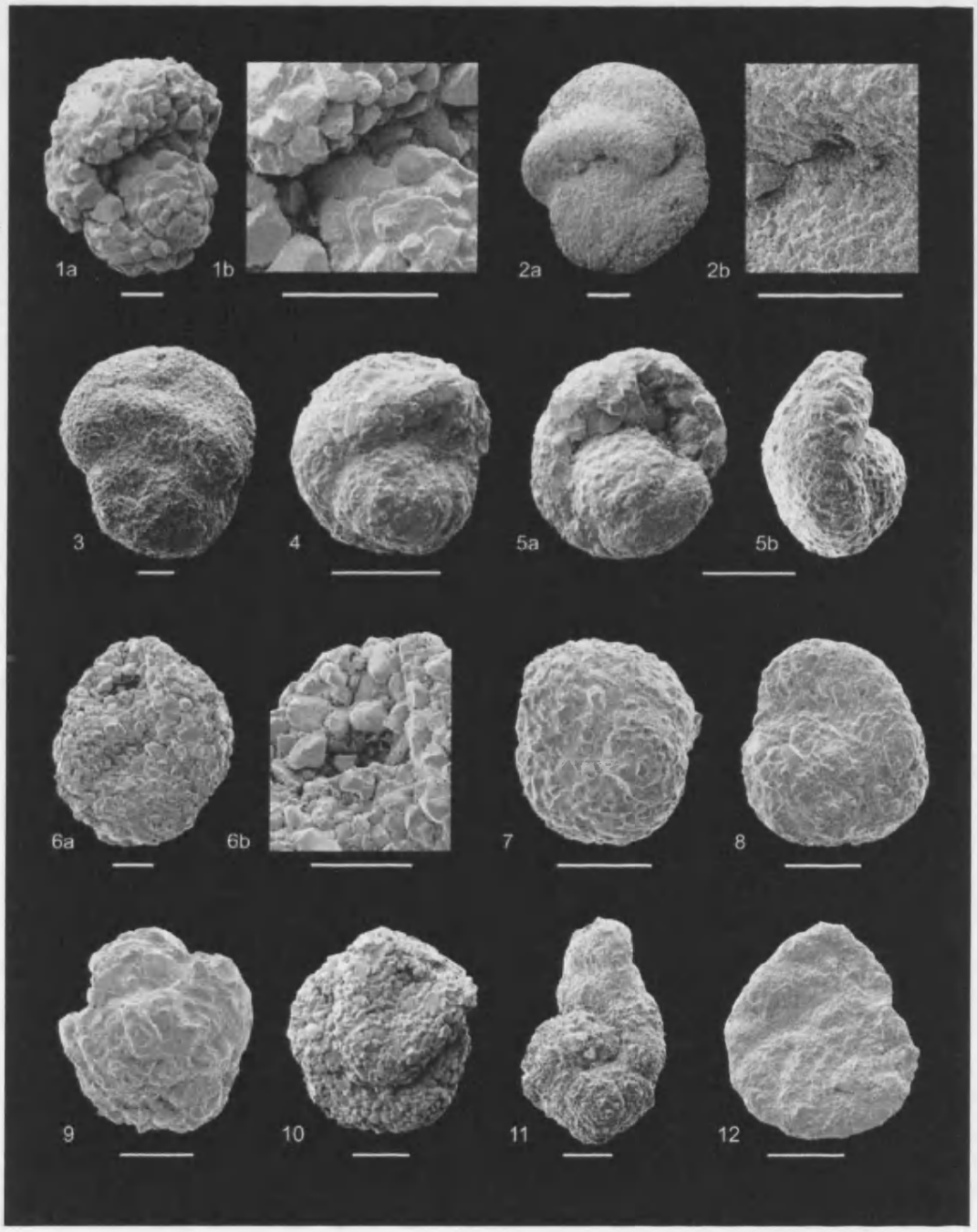


Plate 39. **1.** *Cribrostomoides* sp., 3860m. **2.** *Recurvoides azuaensis*, 3760m. **3.** *Recurvoides azuaensis*, 4090m. **4.** *Recurvoides* sp.1, 3860m. **5.** *Recurvoides* sp.1, 3860m. **6.** *Recurvoides* sp.2, 3940m. **7.** *Recurvoides* sp.3, 4090m. **8.** *Recurvoides* sp.3, 4090m. **9.** *Recurvoides* sp.3, 4170m. **10.** *Recurvoides* sp., 3860m. **11.** *Bulbobaculites* sp.1, 3910m. **12.** *Spiropsammina primula*, 3860m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

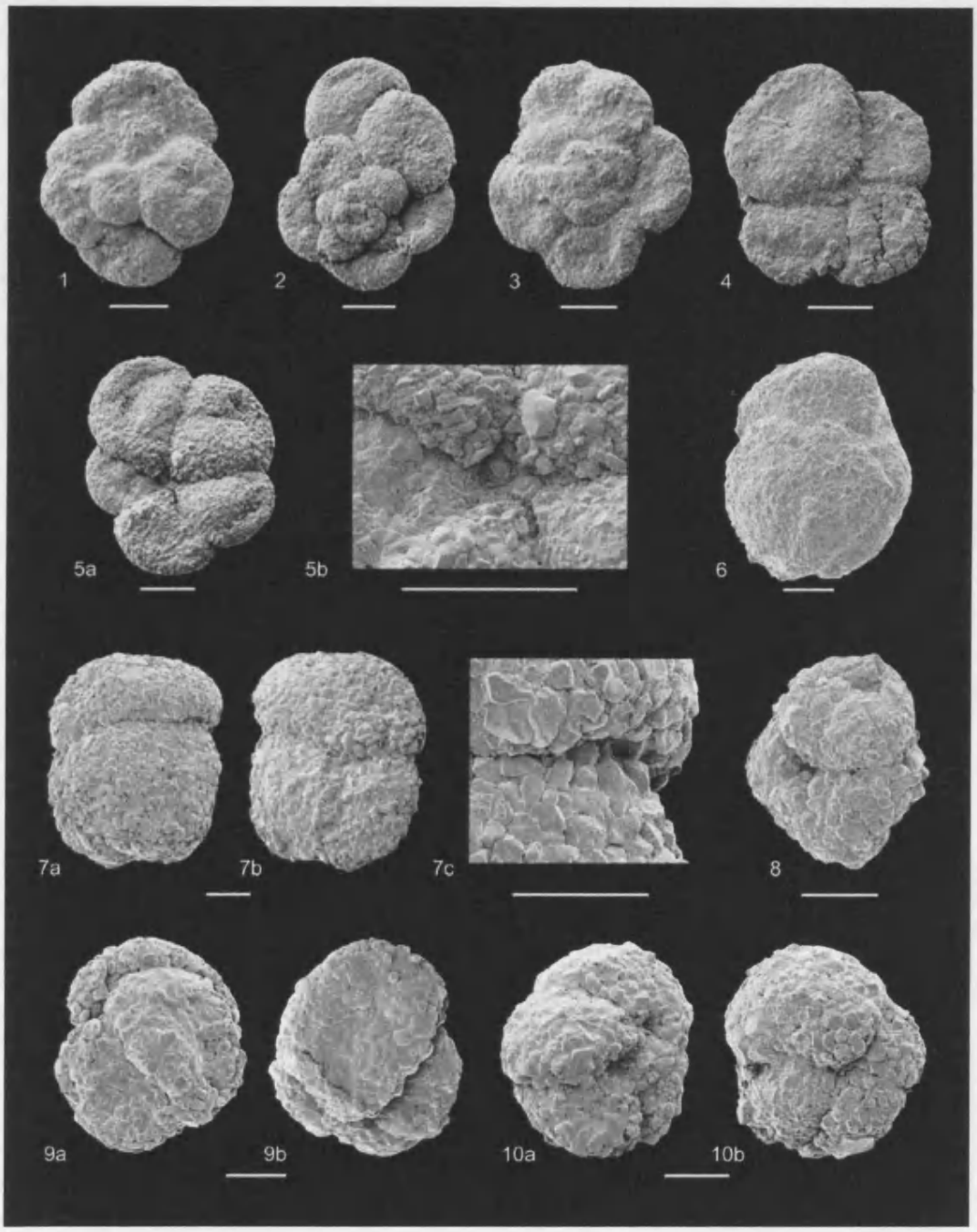


Plate 40. **1.** *Portatrochammina profunda*, 3860m. **2.** *Portatrochammina profunda*, 3830m. **3.** *Portatrochammina profunda*, 3860m. **4.** *Portatrochammina profunda*, 3800m. **5.** *Portatrochammina profunda*, 3840m. **6.** *Tritaxis* sp.1, 4070m. **7.** *Tritaxis* sp.1, 3830m. **8.** *Trochammina* sp.1, 3820m. **9.** *Trochammina* sp.1, 3820m. **10.** *Trochammina* sp., 3900m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

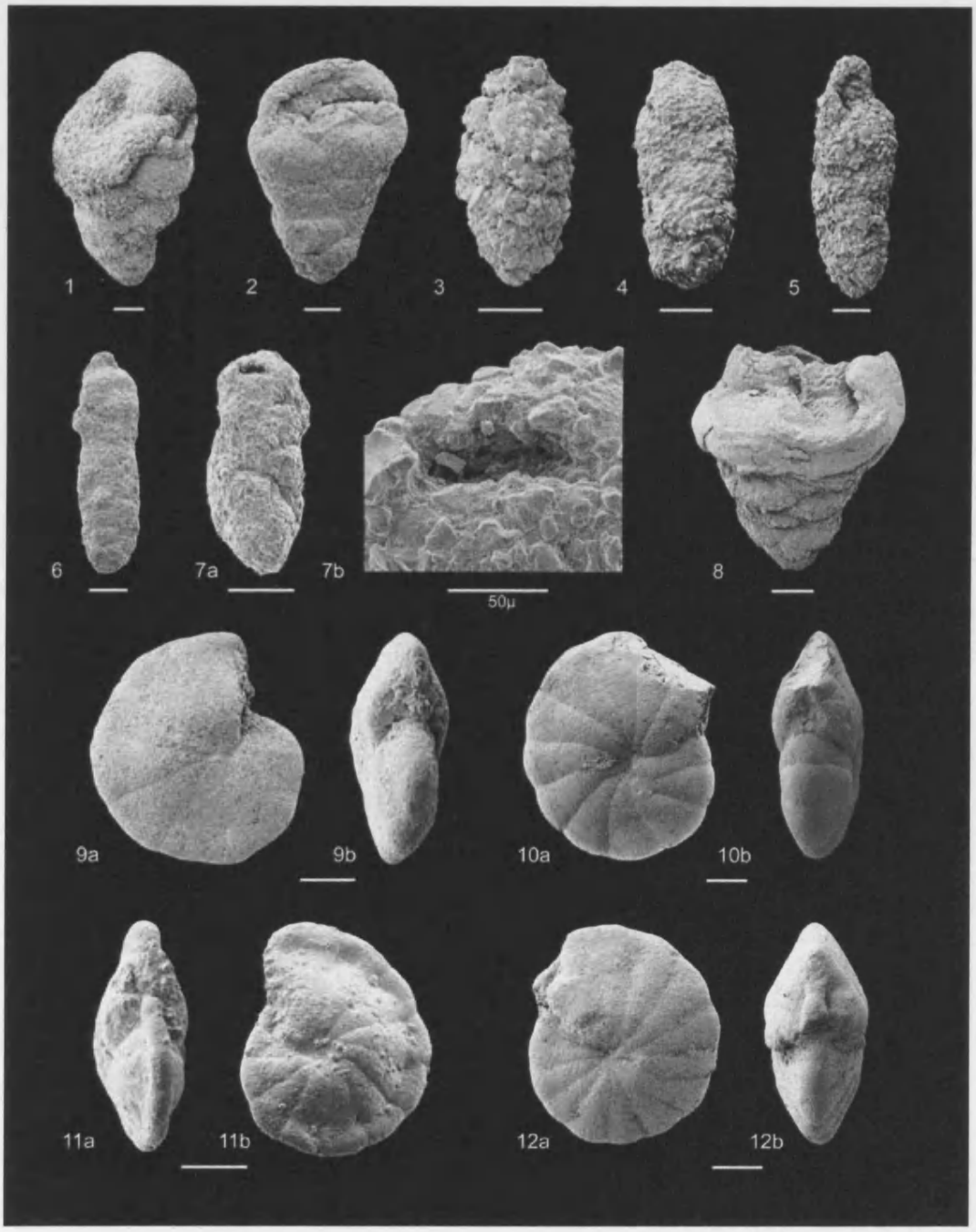


Plate 41. 1. *Eggerelloides* sp.1, 3870m. **2.** *Eggerelloides* sp.1, 3850m. **3.** *Karrerulina apicularis*, 3780m. **4.** *Karrerulina apicularis*, 3860m. **5.** *Karrerulina conversa*, 3830m. **6.** *Karrerulina conversa*, 3830m. **7.** *Karrerulina horrida*, 4090m. **8.** *Verneuilina* sp.1, 3770m. **9.** *Reticulophragmium acutidorsatum*, 3810m. **10.** *Reticulophragmium acutidorsatum* ssp.1, 4100m. **11.** *Reticulophragmium amplectens*, 3860m. **12.** *Reticulophragmium amplectens* ssp.1, 3860m. All scale bars 200µm unless otherwise indicated. All specimens from well Plutao-1.

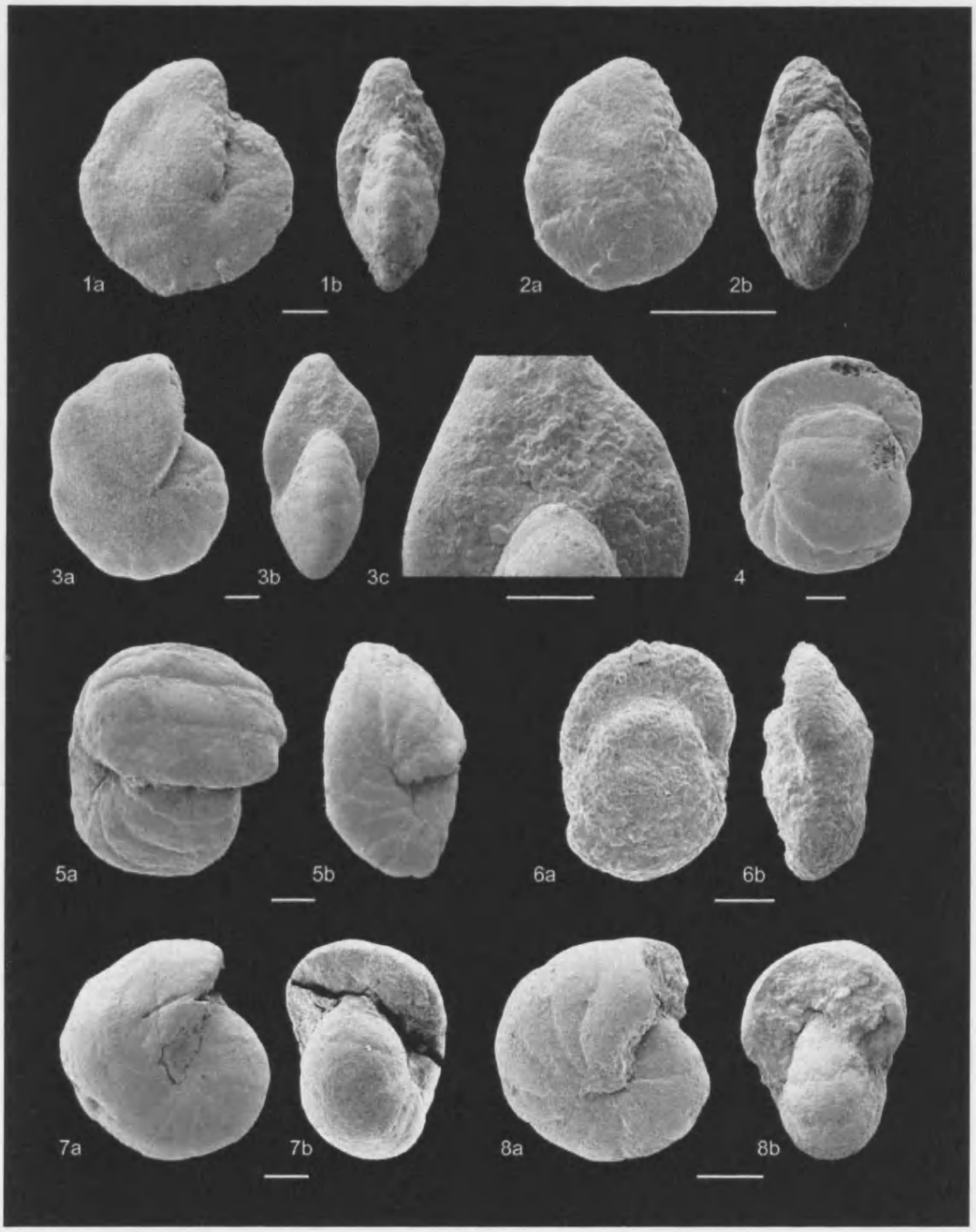


Plate 42. **1.** *Reticulophragmium amplectens/acutidorsatum* transitional form, 4090m. **2.** *Reticulophragmium intermedium*, 4120m. **3.** *Reticulophragmium gasparense*, 3840m. **4.** *Reticulophragmium rotundidorsatum*, 4100m. **5.** *Reticulophragmium rotundidorsatum*, 4100m. **6.** *Reticulophragmium* sp.1, 3930m. **7.** *Cyclammina* aff. *orbicularis*, 4010m. **8.** *Cyclammina* aff. *orbicularis*, 3840m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

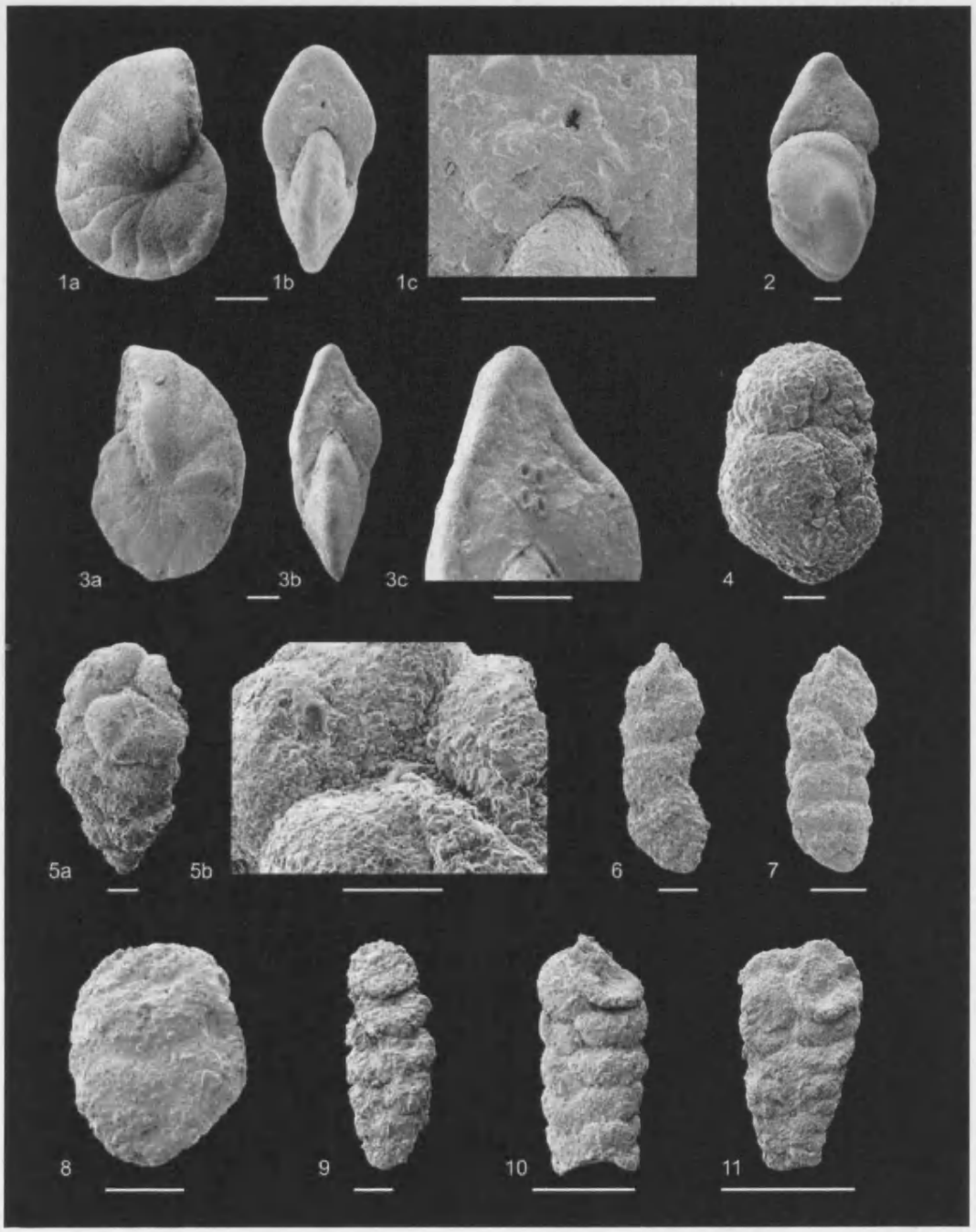


Plate 43. **1.** *Cyclammina* sp.1, 3040m. **2.** *Cyclammina* sp.2, 3930m. **3.** *Cyclammina* sp.2, 3040m. **4.** *Alveovalvulina* sp., 3910m. **5.** *Alveovalvulina* sp.1, 3810m. **6.** *Alveovalvulina crassa*, 3870m. **7.** *Alveovalvulina crassa*, 3870m. **8.** *Valvulina flexilis*, 3630m. **9.** *Haeuserella* sp.1, 3830m. **10.** *Textularia earlandi*, 3820m. **11.** *Textularia earlandi*, 3860m. All scale bars 200μm unless otherwise indicated. All specimens from well Plutao-1.

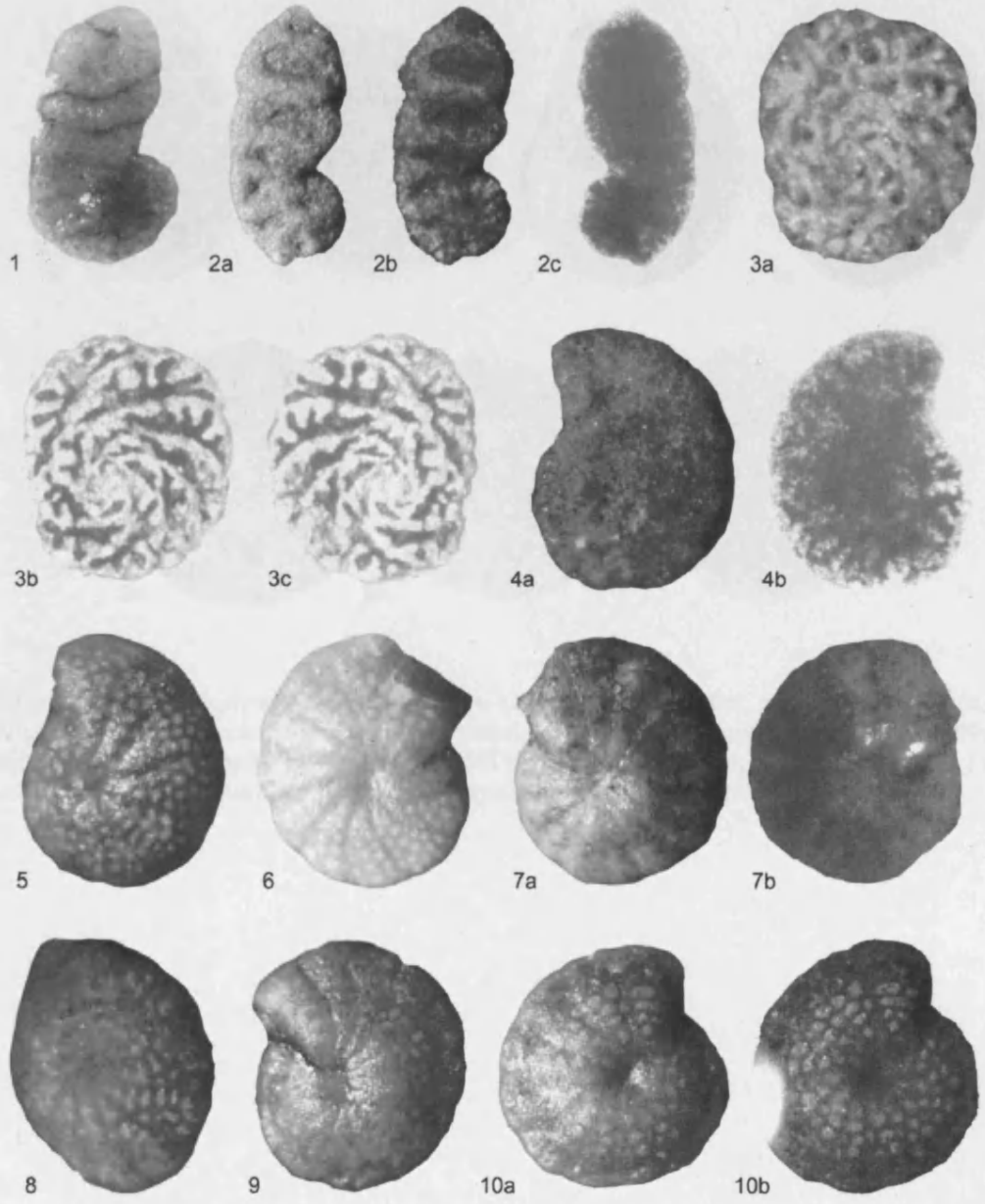


Plate 44. **1.** *Discamminoides* sp.1, (818μm width) 4100m, reflected light, water immersed. **2.** *Discamminoides* sp.1, (654μm width) 4030m, a. reflected light, b. reflected light, water immersed, c. transmitted light. **3.** *Spiropsammina primula*, (473μm width) 4170m, a. reflected light, b,c. transmitted light. **4.** *Popovia* sp.1, (654μm width) 3840m, a. reflected light, b. transmitted light. **5.** *Reticulophragmium acutidorsatum*, (600μmm width) 4180m, reflected light. **6.** *Reticulophragmium acutidorsatum* ssp.1, (1018μm width) 4100m, reflected light. **7.** *Reticulophragmium amplectens* ssp. 1, (745μm width) 3860m, a. reflected light, b. reflected light, water immersed. **8.** *Reticulophragmium amplectens* ssp. 1, (764μm width) 4170m, reflected light, water immersed. **9.** *Reticulophragmium amplectens/acutidorsatum* transitional form, (1000μmm width) 4190m, reflected light. **10.** *Reticulophragmium amplectens/acutidorsatum* transitional form, (891μm width) 4180m, a. reflected light, b. reflected light, water immersed.

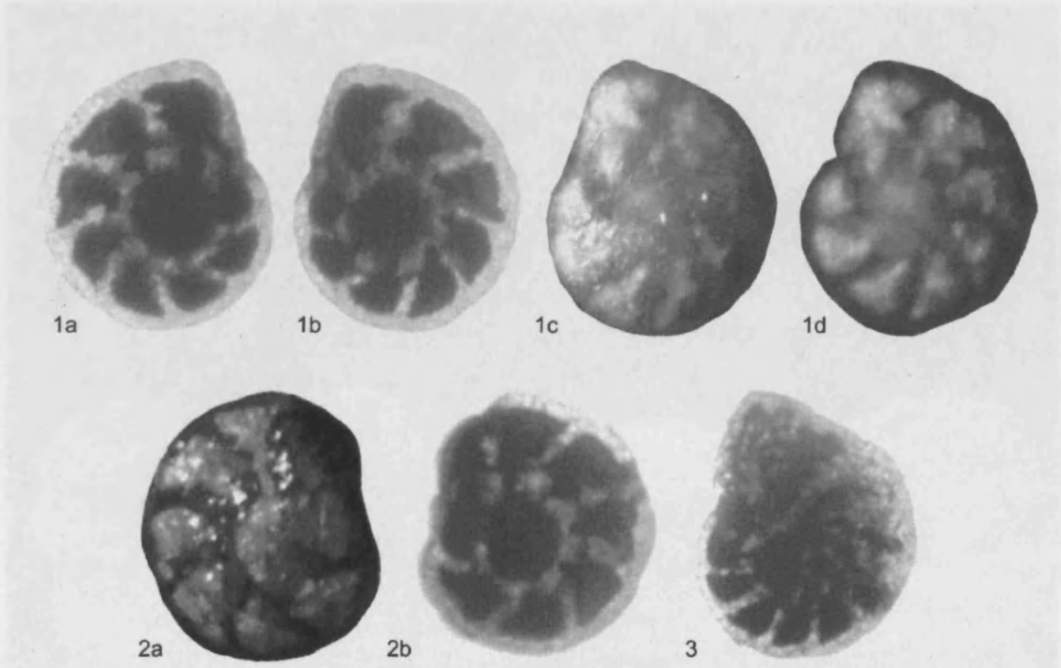


Plate 45. **1.** *Reticulophragmium intermedium*, (291μm width) 4110m, a,b. transmitted light, c. reflected light, d. reflected light, water immersed. **2.** *Reticulophragmium intermedium*, (309μm width) 4100m, a. reflected light, b. transmitted light. **3.** *Reticulophragmium intermedium*, (455 μm width) 4100m, transmitted light. All specimens from well Plutao-1.

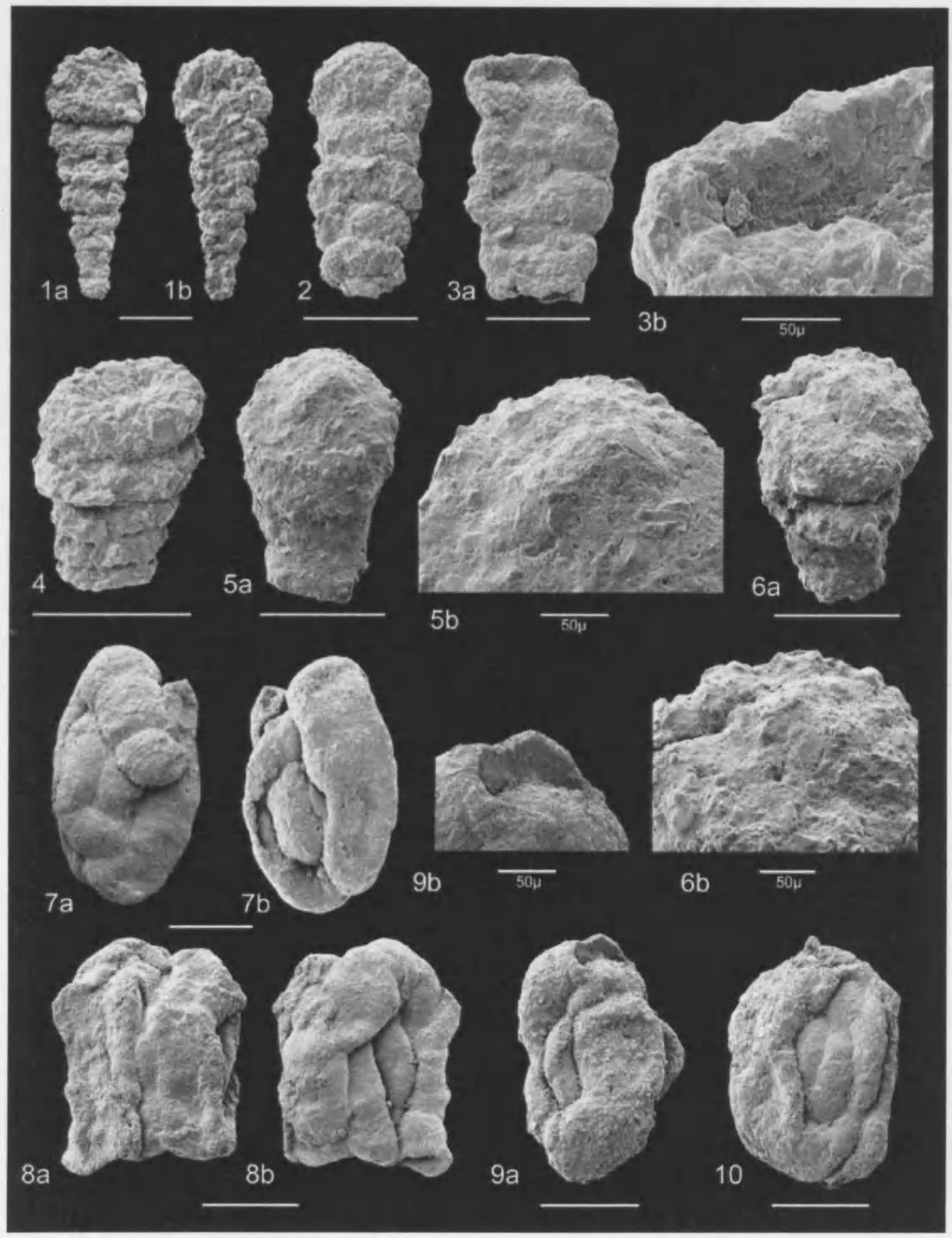


Plate 46. 1-6. *Scherochorella congoensis* Kender, Kaminski and Jones, 2006. 1a-b. Holotype, Sample at 4040m, 2-6. Paratypes, Sample at 4040m.
7-10. *Paratrochamminoides gorayskiformis* Kender, Kaminski and Jones, 2006. 7a,b. Holotype, Sample at 3850m, 8a,b. Paratype, samples at 3830m, 9a,b. Paratype, sample at 3830m, 10. Paratype, sample at 3870m.
Scale bar = 200µm (unless indicated). All specimens from well Plutao-1.

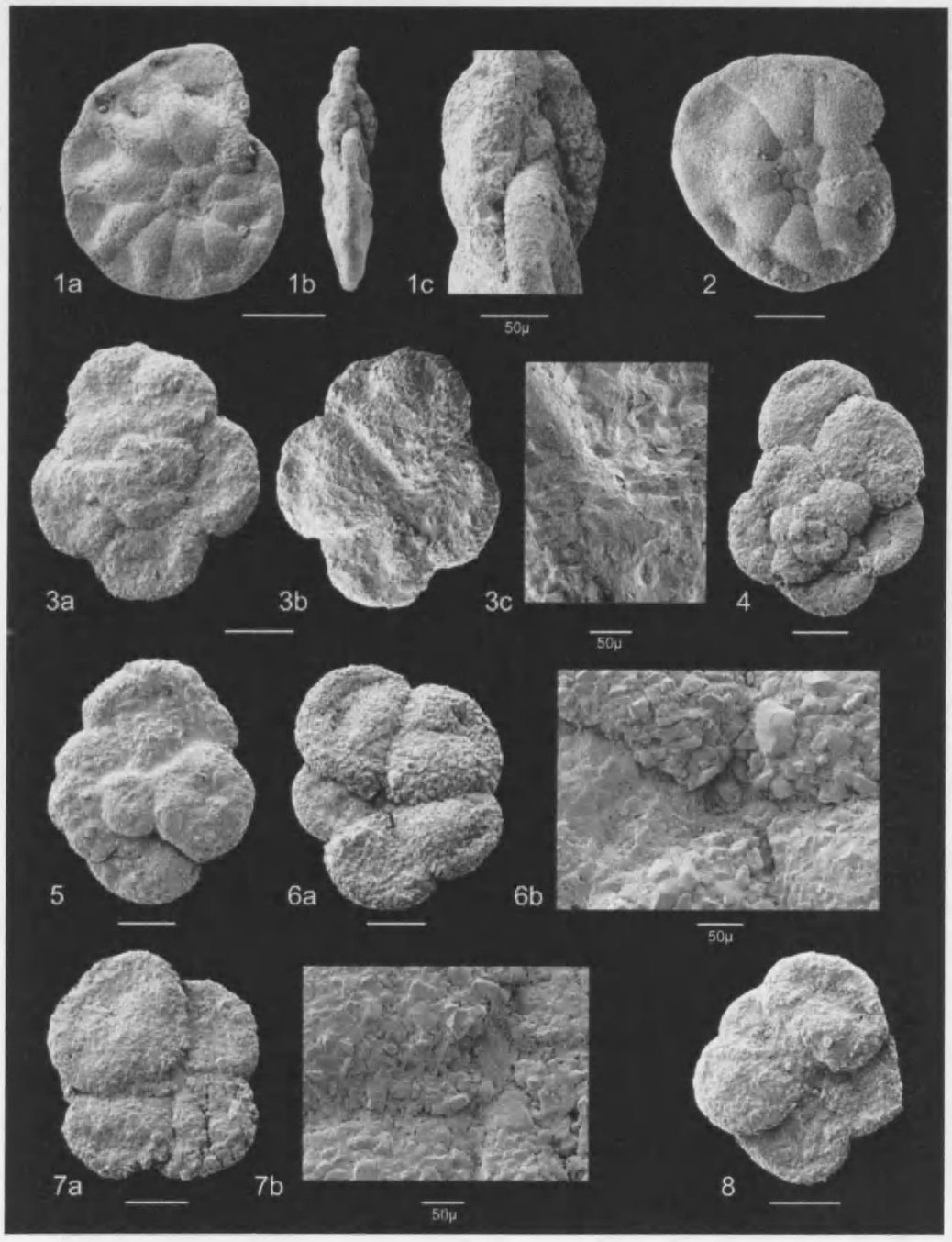


Plate 47. 1-2. *Haplophragmoides nauticus* Kender, Kaminski and Jones, 2006. 1a,b. Holotype, Sample at 3840m, 2. Paratype, sample at 3800m.
3-8. *Portatrochammina profunda* Kender, Kaminski and Jones, 2006. 3a,b. Paratype, Sample at 3860m, 4. Paratype, Sample at 3830m, 5. Paratype, Sample at 3860m, 6a,b. Holotype, Sample at 3840m, 7a,b. Paratype, Sample at 3800m, 8. Paratype, Sample at 3860m.
Scale bar = 200µm (unless indicated). All specimens from well Plutao-1.

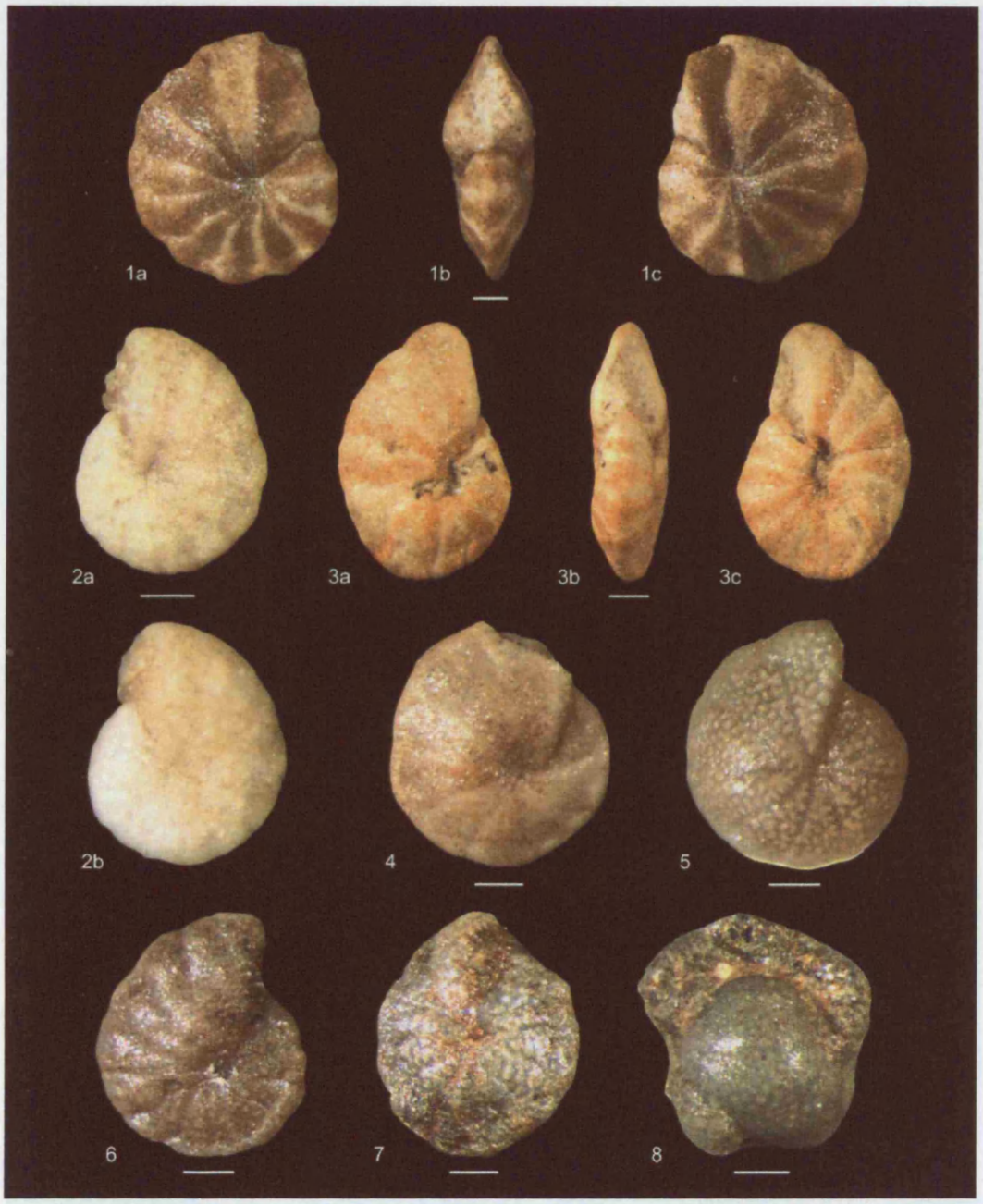


Plate 48. 1. *Reticulophragmium acutidorsatum*, 3380m. **2.** *Reticulophragmium acutidorsatum*, 3040m. **3.** *Reticulophragmium acutidorsatum*, 3340m. **4.** *Reticulophragmium acutidorsatum*, 3840m. **5.** *Reticulophragmium acutidorsatum*, 4170m. **6.** *Reticulophragmium acutidorsatum*, 4230m. **7.** *Reticulophragmium acutidorsatum*, 4220m. **8.** *Reticulophragmium rotundidorsatum*, 4220m. Scale bar = 200 μm. All specimens from well Plutao-1.

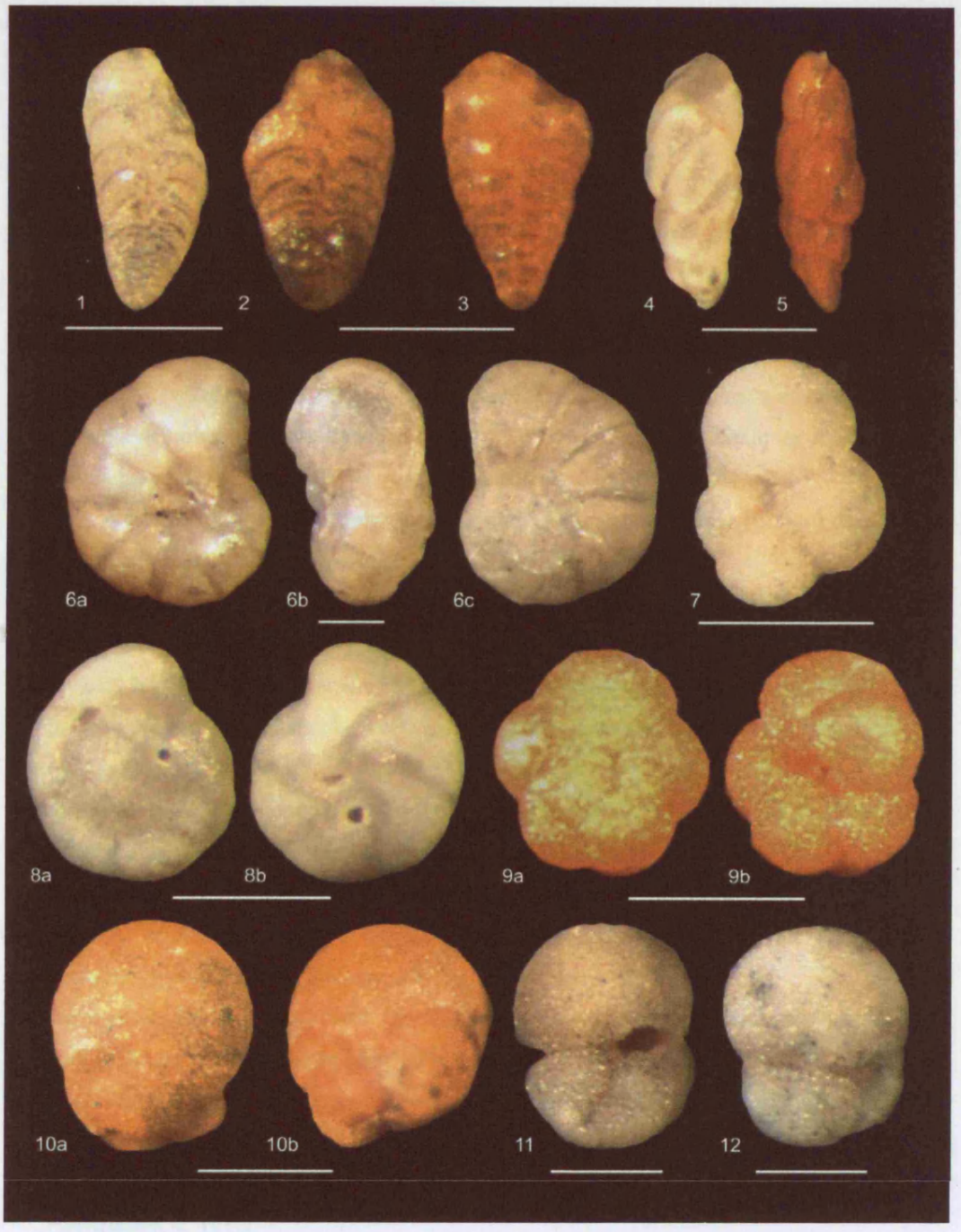


Plate 49. 1. *Brizalina alazanensis*, 2930m. **2.** *Brizalina alazanensis*, 2930m. **3.** *Brizalina alazanensis*, 2930m. **4.** *Bulimina elongata*, 2930m. **5.** *Bulimina elongata*, 2930m. **6.** *Valvulineria pseudotumeyensis*, 2920m. **7.** *Globigerina praebulloides*, 2930m. **8.** *Oridorsalis umbonatus*, 3160m. **9.** *Globorotaloides suteri*, 2930m. **10.** *Praeorbulina glomerosa glomerosa*, 2920m. **11.** *Globigerinoides trilobus*, 3160m. **12.** *Globigerinoides trilobus*, 3160m. Scale bar = 200 μm. All specimens from well Plutao-1.

REFERENCES

Akers, W.H. & Doorman, J.H. 1964. Pleistocene foraminifera of the Gulf Coast. *Tulane Studies in Geology*, **3**, 1-93.

Altenbach, A.V., Pflaumann, U., Schiebel, R., Thies, A., Timm, S. & Trauth, M. 1999. Scaling percentages and distribution patterns of benthic foraminifera with flux rates of organic carbon. *Journal of Foraminiferal Research*, **29**, 173-185.

Alve, E. 1995. Benthic foraminiferal distribution and recolonization of formerly anoxic environments in Drammensfjord, southern Norway. *Marine Geology*, **25**, 169-286.

Anderson, J.E., Cartwright, J., Drysdall, S.J. & Vivian, N. 2000. Controls on turbiditic sand deposition during gravity-driven extension of a passive margin: examples from Miocene sediments in Block 4, Angola. *Marine and Petroleum Geology*, **17**, 1165-1203.

Anka, Z. & Séranne, M. 2004. Reconnaissance study of the ancient Zaire (Congo) deep-sea fan (ZaiAngo Project). *Marine Geology*, **209**, 223-244.

Asano, K. 1950. Illustrated catalogue of Japanese Tertiary smaller foraminifera. *In.* Stach, L.W. et al. (eds), Tokyo, Japan, **3**, 7 pp.

Babonneau, N., Savoye, B., Cremer, M. & Klein, B. 2002. Morphology and architecture of the present canyon and channel system of the Zaire deep-sea fan. *Marine and Petroleum Geology*, **19**, 445-467.

Barker, R.W. 1960. Taxonomic notes on the species figured by H. B. Brady in his report on the foraminifera dredged by H. M. S. Challenger during the years 1873-1876. *Society of Economic Paleontologists and Mineralogists, Special Publication*, **9**, 238 pp.

Barron, J.A. & Keller, G. 1983. Widespread Miocene deep-sea hiatuses: Coincidence with periods of global cooling. *Geology*, **10**, 577-581.

Barron, J.A. & Baldauf, J.G. 1990. Development of biosiliceous sedimentation in the North Pacific during the Miocene and Early Pliocene. *In:* Tsuchi, R. (Ed.), *Pacific Neogene Events: Their Timing, Nature and Interrelationships,* Tokyo (University of Tokyo Press), 43-63.

Becker, L.E. & Dusenbury, A.M., Jr. 1958. Miod-Oligocana (Aquitanian) foraminifera from the Goajira Peninsula, Columbia. *Cushman Laboratory for Foraminiferal Research Special Publication*, **4**, 48 pp.

Beckmann, J.P. 1953. Die Foraminiferan der Oceanic Formation (Eocaen-Oligocaen) von Barbados. *Eclogae Geologicae Helvetiae*, **46**, 301-412.

Belford, D.J. 1966. Miocene and Pliocene smaller foraminifera from Papua and New Guinea. *Department of Natural Development, Bureau Mineral Resources, Geology and Geophysics, Commonwealth of Australia, Bulletin*, **79**, 1-305.

Bender, H. 1995, Test structure and classification in agglutinated formaminifera. *In*: Kaminski, M.A., Geroch, s. & Gasiński, M.A. (Eds). Proceedings of the Fourth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **3**, 27-70.

Bentahila, Y., Hebrard, O., Othman, D.B., Luck, J.-M., Séranne, M. & Lopez, M. 2006. Gulf of Guinea continental slope and Congo (Zaire) deep-sea fan: Sr–Pb isotopic constraints on sediments provenance from ZaiAngo cores. *Marine Geology*, **226**, 323-332.

Benzecri, J.P. 1992. *Correspondence analysis handbook.* CRC Press, London, 688 pp.

Berggren, W.A. & Kaminski, M.A. 1990. Abyssal Agglutinates: Back to Basics. *In*: Hemleben, C., Kaminski, M.A., Kuhnt, W. & Scott, D.B. (Eds). *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera,* NATO ASI Series C327, Kluwer Academic Publication, Dordrecht etc., 53-76.

Berggren, W.A., Kent, D.V., Swisher, C.C. & Aubry, M.-P. 1995. A revised Cenozoic Geochronology and Chronostratigraphy. *SEPM Special Publication*, **54**, 129-212.

Berhard, J.M., Sen Gupta, B.K. & Borne, P.F. 1997. Benthic foraminiferal proxy to estimate dysoxic bottom-water oxygen concentrations: Santa Barbara Basin, U.S. Pacific continental margin. *Journal of Foraminiferal Research*, **27**, 301-310.

Bermúdez, P.J. 1949. Tertiary smaller foraminifera of the Dominican Republic. *Cushman Laboratory of Foraminiferal Research, Special Publication*, **25**, 322 pp.

Bermúdez, P.J. & De Rivero, F.C. 1963. Estudio sistematico de los Foraminiferos Quitinosos, Mikrogranulares y Arenaceos. *Universidad Central de Venezuela, Ediciones de la Biblioteca*, 398 pp.

Bermúdez, P.J. & Fuenmayor, A.N. 1966. Consideraciones sobre los Sedimentos del Mioceno Medio al Reciente de las Costas Central y Oriental de Venezuela. *Ministerio de Minas e Hidrocarburos Direccion de Geologia*, **7**, 414-611.

Berry, E.W. 1928. The smaller foraminifera of the Middle Lobitos shales of northwestern Peru. *Ecologae Geologicae Helvetiae*, **21**, 390-405.

Blow, W.H. 1959. Age, correlation, and biostratigraphy of the upper Tocuto (San Lorenzo) and Pozon formations, eastern Falcon, Venezuela. *Bulletins of American Paleontology*, **39**, 67-215.

Billups, K. & Schrag, D.P. 2002. Paleotemperatures and ice volume of the past 27 Myr revisited with paired Mg/Ca and $^{18}O/^{16}O$ measurements on benthic foraminifera. *Paleoceanography*, **17** (PA000567), 3-1–3-11.

Blow, W.H. 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In:* Brönnimann, P. & Renz, H.H. (Eds.), *Proceedings of the First International Conference on Planktonic Microfossils, Geneva, Leiden*, **1**, 199-421.

Boersma, A. 1984. *Handbook of Common Tertiary Uvigerina.* Microclimates Press, Stony Point, New York, 207 pp.

Bolli, H.M. 1957. Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua formations of Trinidad, B.W.I. *Bulletin of the US National Museum*, **215**, 97-123.

Bolli, H.M., Beckmann, J.P. & Saunders, J.B. 1994. *Benthic Foraminiferal Biostratigraphy of the South Caribbean Region.* Cambridge University Press, Cambridge, 408 pp.

Bolli, H.M. & Saunders, J.B. 1985. Oligocene to Holocene low latitude planktonic foraminifera. *In:* Bolli, H.M., Saunders, J.B. & Perch-Nielsen, K. (Eds.). *Plankton Stratigraphy*, Cambridge Earth Sciences Series, Cambridge University Press, Cambridge, 155-262.

Bond, G. 1978. Evidence for late Tertiary uplift of Africa relative to North America, South America, Australia and Europe. *Journal of Geology*, **86**, 47-65.

Bornemann, J.G. 1855. Die mikroskopische fauna des Septarienthones von Hermsdorf bei Berlin. *Deutschen Geologischen Gesellschaft, Zeitschrift*, **7**, 307-371.

Bown, P.R. 1998. *Calcareous Nannofossil Biostratigraphy.* British Micropalaeontological Society Publication Series, Chapman and Hall (Kluwer Academic Publishers), 315 pp.

Brady, H.B. 1877. Supplementary note on the foraminifera of the chalk (?) of the New Britain Group. *Geological Magazine,* (new series, decade 2), **4**, 534-536.

Brady, H.B. 1878. On the reticularian and radiolarian rhizopoda (Foraminifera and Polycystina) of the North-Polar Expedition of 1875, 1876. *Annals and Magazine of Natural History,* series 5, **1**, 425-440.

Brady, H.B. 1879. Notes on some of the reticularian Rhizopoda of the "*Challenger*" Expedition; Part I. On new or little known Arenaceous types. *Quarterly Journal of Microscopical Sciences,* **19**, 20-67.

Brady, H.B. 1881. Notes on some of the reticularian Rhizopodia of the '*Challenger*' Expedition; Part III. 1. Classification. 2. Further notes on new species. 3. Note on Biloculina mud. *Quarterly Journal Microscopical Science*, **21**, 31-71.

Brady, H.B. 1884. Report on the foraminifera dredged by HMS *Challenger*, during the years 1873-1876. *Report of Scientific Results of the Exploration Voyage of HMS* Challenger. (Zoology), **9**, 1-814.

Brady, H.B., Parker, W.K. & Jones, T.R. 1888. On some foraminifera from the Abrolhos Bank. *Zoological Society of London, Transactions*, **12**, 211-239.

Brönnimann, P. 1954. Appendix: Descriptions of new species. *In:* Todd, R., Cloud, P.E. Jr., Low, D. & Schmidt, R.G. Probable occurrence of Oligocene on Saipan. *American Journal of Science*, **252**, 673-682.

Broucke, O.,Temple, F., Rouby, D., Robin, C., Calassou, S., Nalpas, T. & Guillocheau, F. 2004. The role of deformation processes on the geometry of mud-dominated turbiditic systems, Oligocene and Lower–Middle Miocene of the Lower Congo basin (West African Margin). *Marine and Petroleum Geology,* **21**, 327–348.

Brouwer, J. 1965. Agglutinated foraminiferal faunas from some turbitic sequences. I. *Koninklije Nederlandse Akademie van Weterschappen, Proceedings, Series B*, **68**, 309-334.

Cameron, A. 1978. Neogene benthic foraminifera from DSDP Sites 360 and 362, southeastern Atlantic. *In*: Bolli, H.M., Ryan, W.B.F., et al. (Eds.), *Initial Reports DSDP*, **40**, Washington (U.S. Government Printing Office), 811-819.

Chapman, F., Parr, W.J. & Collins, A.C. 1934. Tertiary foraminifera of Victoria, Australia. The Balcombian deposits of Port Phillip; Part III. *Zoological Journal of the Linnaean Society of London*, **38**, 553-77.

Charnock, M.A. & Jones, R.W. 1990. Agglutinated foraminifera from the Paleogene of the North Sea. *In*: Hemleben, C., Kaminski, M.A., Kuhnt, W., & Scott, D.B. (Eds). *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera, NATO ASI Series,* Kluwer Academic Publication, Dordrecht etc, 139-244.

Charnock, M.A. & Jones, R.W. 1997. North Sea Lituolid foraminifera with complex inner structures: taxonomy, stratigraphy and evolutionary relationships. *Annales Societatis Geologorum Poloniae*, **67**, 183-196.

Chenouard, L., de Klasz, I. & Meijer, M. 1960. Deux nouvelles espèces du genre *Siphogenerinoides* (Foraminifère) du Crétacé superieur de l'Afrique occidentale. *Revue de Micropaléontologie*, **3**, 71-76.

Cicha, I., Rögl, F., Rupp, C. & Ctyroka, J., 1998. Oligocene-Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, **549**, 1-325.

Cimerman, F. & Langer, M.R. 1991. Mediterranean Foraminifera. *Academia Scientiarum et Artium Slovenica.* (Classis 4), **30**, 118 pp.

Corliss, B.H. 1985. Microhabitats of benthic foraminifera within deep-sea sediments. *Nature*, **314**, 435-438.

Corliss, B.H. 1991. Morphology and microhabitat preferences of benthic foraminifera from the northwest Atlantic Ocean. *Marine Micropaleontology*, **17**, 195-236.

Cramez, C. & Jackson, M.P.A. 2000. Superposed deformation straddling the continental-oceanic transition in deep-water Angola. *Marine and Petroleum Geology*, **17**, 1095-1109.

Culver, S.J. 1988. New foraminiferal depth zonation of the northwestern Gulf of Mexico. *Palaios*, **3**, 69-85.

Cushman, J.A. 1910. A monograph of the foraminifera of the North Pacific Ocean. Astrorhizidae and Lituolidae. *Smithsonian Institution, United States National Museum, Bulletin*, **71**, 1-134.

Cushman, J.A. 1911. A monograph on the foraminifera of the North Pacific Ocean; Part II - Textulariidae. *United States National Museum Bulletin*, **71**, 108 pp.

Cushman, J.A. 1918. Some Pliocene and Miocene Foraminifera of the Coastal Plain of the United States. *United States Geological Survey Bulletin*, **676**, 100 pp.

Cushman, J.A. 1922. The foraminifera of the Atlantic Ocean; Part III - Textulariidae. *United States National Museum Bulletin*, **104**, 149 pp.

Cushman, J.A. 1923. The foraminifera of the Vicksburg group. *U.S. Geological Survey, Professional Paper, Washington, D.C., U.S.A.*, **133**, 11-71.

Cushman, J.A. 1929. A late Tertiary fauna of Venezuela and other related regions. *Cushman Laboratory of Foraminiferal Research, Contributions*, **5**, 77-101.

Cushman, J.A. 1930. The foraminifera of the Choctawhatchee Formation of Florida. *Florida State Geological Survey Bulletin*, **4**, 5-89.

Cushman, J.A. 1932. The genus *Vulvulina* and its species. *Cushman Laboratory of Foraminiferal Research, Contributions*, **8**, 75-85.

Cushman, J.A. 1934. The generic position of "Cornuspira cretacea Reuss". *Contributions from the Cushman Laboratory for Foraminiferal Research*, **10**, 44-47.

Cushman, J.A. 1937a. A monograph of the foraminiferal family *Valvulinidae. Cushman Laboratory of Foraminiferal Research Special Publication*, **8**, 210 pp.

Cushman, J.A. 1937b. A monograph of the foraminiferal subfamily *Virgulininae* of the foraminiferal family *Buliminidae. Cushman Laboratory of Foraminiferal Research Special Publication*, **9**, 228 pp.

Cushman, J.A. 1946. The genus *Sigmoilina* and its species. *Contributions from the Cushman Laboratory of Foraminiferal Research*, **22**, pt. 2, 29-45.

Cushman, J.A. & Bermúdez, P.J. 1937. Further new species of foraminifera from the Eocene of Cuba. *Contributions from the Cushman laboratory of Foraminiferal Research*, **13**, 1-29.

Cushman, J.A. & Cahill, E.D. 1933. Miocene Foraminifera of the Coastal Plain of the Eastern United States. *U.S. Geological Survey, Professional Paper*, **175-A**, p. 1-50.

Cushman, J.A. & Ellisor, A.O. 1939. New species of foraminifera from the Oligocene and Miocene. *Contributions from the Cushman Laboratory of Foraminiferal Research*, **15**, 1-14.

Cushman, J.A. & Harris, R.W. 1927. Some notes on the genus *Ceratobulimina. Contributions from the Cushman laboratory of Foraminiferal Research*, **3**, pt. 4 (51), 171-179.

Cushman, J.A. & Jarvis, P.W. 1928. Cretaceous foraminifera from Trinidad. *Contributions from the Cushman Laboratory of Foraminiferal Research*, **4**, 85-103.

Cushman, J.A. & Jarvis, P.W. 1930. Miocene foraminifera from Buff Bay, Jamaica. *Journal of Paleontology*, **4**, 353-368.

Cushman, J.A. & Jarvis, P.M. 1934. Some interesting new uniserial foraminifera from Trinidad. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **10**, 71-75.

Cushman, J.A. & Jarvis, P.W. 1936. Three new Foraminifera from the Miocene Bowden Marl, of Jamaica. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **12**, 3-5.

Cushman, J.A. & Parker, F.L. 1936. Some American Eocene Buliminas. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **12**, 39-45.

Cushman, J.A. & Parker, F.L. 1939. Bulimina macilenta Cushman and Parker, a new name. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **15**, 93-94.

Cushman J.A. & Parker, F.L. 1940. The species of the genus Bulimina having Recent types. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **16**, 7-23.

Cushman, J.A. & Renz, H.H. 1941. New Oligocene-Miocene foraminifera from Venezuela. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **17**, 1-27.

Cushman, J.A. & Renz, H.H. 1946. The foraminiferal fauna of the Lizard Springs Formation, British West Indies. *Cushman Laboratory of Foraminiferal Research, Special Publication*, **18**, 1-48.

Cushman, J.A. & Renz, H.H. 1947. The foraminiferal fauna of the Oligocene Ste. Croix Formation of Trinidad, British West Indies. *Contributions from the Cushman Laboratory for Foraminiferal Research, Special Publication*, **22**, 1-46.

Cushman, J.A. & Stainforth, R.M. 1945. The foraminifera of the Cipero marl formation of Trinidad, British West Indies. *Cushman Laboratory for Foraminiferal Research Special Publication*, **14**, 91 pp.

Cushman, J.A. & Todd, R. 1945. Miocene foraminifera from Buff Bay, Jamaica. *Cushman Laboratory of Foraminiferal Research, Special Publication*, **15**, 73 pp.

Czjzek, J. 1848. Beitrag zur Kenntniss der fossilien Foraminiferen des Wiener Backens. *Naturwissenschaftliche Abhandlungen*, **2**, pt. 1, 137-150.

de Klasz, I., Marie, P. & Meijer, M. 1960. *Gabonella* nov. gen., un nouveau genre de Foraminifères du Crétacé superieur et du Tertiaire basal de l'Afrique occidentale. *Revue de Micropaléontologie*, **5**, 69-74.

de Klasz, I., Magné, J. & Rérat, D. 1963. Quelques formes nouvelles de Buliminidae characteristiques du Crétacé superieur du Gabon (Afrique Equatoriale). *Revue de Micropaléontologie*, **6**, 145-152.

de Klasz, I. & Rérat, D. 1962a. Quelques nouvelles espèces du genre *Buliminella* du Crétacé superieur du Gabon (Afrique Equatoriale). *Revue de Micropaléontologie*, **5**, 69-74.

de Klasz, I. & Rérat, D. 1962b. Quelques noveaux Foraminifères du Crétacé et du Tertiaire du Gabon (Afrique Equatoriale). *Revue de Micropaléontologie*, **4**, 175-189.

Dellamonica, X.L.N. 2004. *Biostratigraphic Data for Reservoir Correlation and the Prediction of Basin-fill Evolution in Sand-rich Turbidite Successions.* Unpublished Ph.D. Thesis, University of Aberdeen, 250 pp.

De Matos, R.M. 1999. History of Northeast Brazilian rift system: kinematic implications for the breakup between Brazil and West Africa. *In*: Cameron, N.R., Bate, R.H. & Clure, V.S. (Eds). *The Oil and Gas Habitats of the South Atlantic. Special Publication of the Geological Society of London,* **153**, 55-73.

De Rijk, S., Jorissen, F.J., Rohling, E.J. & Troelstra, S.R. 2000. Organic flux control on bathymetric zonation of Mediterranean benthic foraminifera. *Marine Micropaleontology*, **40**, 151-166.

de Stefani, T. 1952. Su alcune manifestazoini di idrocarburi in provincial di Palermo e descrizione di foraminiferi nuovi. *Plinia,* **3**, 1-12.

Díaz de Gamero, M. L., 1985. Micropaleontología de la Formación Agua Salada, Falcón nororiental, *VI Congreso Geologico Venezolano, Sociedad Venezolano de Geologos*, **1**, 384-453.

Ellis, B.F. & Messina, A.R. 1940 *et seq. Catalogue of Foraminifera.* American Museum of Natural History Special Publication. New York.

Earland, A. 1933. Foraminifera. Part II. South Georgia. *Discovery Reports*, 7, 29-138.

Evans, D. 2002. Shallow clues for deep exploration. *Oilfield Review*, **14** (4), 2-13.

Faulkner, J.S., de Klasz, I. & Rérat, D. 1963. *Megastomella* nov. gen. nouveau foraminifère de l'Afrique Occidentale. *Revue de Micropaléontologie*, **6**, 19-22.

Fichtel, L. von & Moll, J.P.C. 1798. *Testacea microscopica aliaque minuta ex generibus Argonauta et Nautilus ad naturam delineate et discripta.* Wien, Anton Pichler, 123 pp.

Filipescu, S. 1996. Stratigraphy of the Neogene from the western border of the Transylvanian Basin. *Studia Universitatis Babes-Bolyai, Geologia*, **2**, 3-78.

Finger, K.L. 1992. Biostratigraphic atlas of Miocene foraminifera from the Monterey and Modelo formations, central and southern California. *Cushman Foundation for Foraminiferal Research Special Publication*, **29**, 179 pp.

Fisher, R.A., Corbet, A.S. & Williams, C.B.1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology*, **12**, 42-58.

Flower, B.J. 1999. Warming without high CO_2? *Nature*, **399**, 313-314.

Flower, B.J. & Kennett, J.P. 1994. The Middle Miocene climatic transition: East Antarctic ice sheet development, deep sea circulation, and global carbon cycling. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **108**, 537-555.

Flower, B.J. & Kennett, J.P. 1995. Middle Miocene deepwater paleoceanography in the southwest Pacific: relations with East Antarctic ice sheet development. *Paleoceanography*, **10**, 1095-1113.

Flower, B.J., Zachos, J.C. & Martin, E. 1997. Latest Oligocene through Early Miocene isotope stratigraphy and deep-water paleoceanography of the western equatorial Atlantic: Sites 926 and 929. *In*: Shackleton, N.J., Curry, W.B., Richter, C. & Bralower, T.J. (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results*, **154**, 451-461.

Fontanier, C., Jorissen, F.J., Chaillou, G., Anschutz, P., Grémare, A. & Griveaud, C. 2005. Live foraminiferal faunas from a 2800 m deep lower canyon station from the Bay of Biscay: Faunal response to focusing of refractory organic matter. *Deep-Sea Research I*, **52**, 1189-1227.

Futyan, A.I. 1976. Late Mesozoic and Early Cainozoic benthic foraminifera from Jordan. *Palaeontology*, **19**, 517-537.

Galloway, J.J. & Morrey, M. 1929. A lower Tertiary foraminiferal fauna from Manta, Ecuador. *Bulletins of American Paleontology*, **15**, 7-56.

Galloway, J.J. & Wissler, S.G. 1927. Pleistocene foraminifera from the Lomita Quarry, Palos Verdes Hills, California. *Journal of Paleontology*, **1**, 35-87.

Geroch, S. & Kaminski, M.A. 1992. The morphology and systematics of Nothia excelsa (Grzybowski), a deep-water agglutinated foraminifer. *Rocznik Polskiego Towarzystwa Geologicznego*, **62**, 255-265.

Giresse, P. 2005. Mesozoic–Cenozoic history of the Congo Basin. *Journal of African Earth Sciences*, **43**, 301-315.

Glaessner, M.F. 1937. Studien über Foraminiferen aus der Kreide und dem Tertiär des Kaukasus; 1. Die Foraminiferen der ältesten Tertiärschichten des Nordwest-Kaukas. *Problems of Paleontology*, **2-3**: 349-408. Moscow.

Gooday, A.J. 2003. Benthic foraminifera (Protista) as tools in deep-water paleoceanography: a review of environmental influences on faunal characteristics. *Advances in Marine Biology*, **46**, 1-90.

Gooday, A.J., Bernhard, J.M., Levin, L.A. & Suhr, S.B. 2000. Foraminifera in the Arabian Sea oxygen minimum zone and other oxygen-deficient settings: taxonomic composition, diversity, and relation to metazoan faunas. *Deep-Sea Research II*, **47**, 25-54.

Gooday, A.J. & Hughes, J.A. 2002. Foraminifera associated with phytodetritus deposits at a bathyal site in the northern Rockall Trough (NE Atlantic): seasonal contrasts and a comparison of stained and dead assemblages. *Marine Micropaleontology*, **46**, 83-110.

Goudie, A.S. 2005. The drainage of Africa since the Cretaceous. *Geomorphology*, **67**, 437-456.

Gradstein, F.M. & Kaminski, M.A. 1989. Taxonomy and biostratigraphy of new and emended species of Cenozoic deep-water agglutinated foraminifera from the Labrador and North Seas. *Micropaleontology*, **35**, 72-92.

Gradstein, F.M. & Kaminski, M.A. 1997. New species of Paleogene deep-water agglutinated foraminifera from the North Sea and Norwegian Sea. *Annales Societatis Geologorum Poloniae*, **67**, 217-229.

Gradstein, F.M., Kaminski, M.A. & Berggren, W.A. 1988. Cenozoic foraminiferal biostratigraphy, Central North Sea. *In*: Rögl, F. & Gradstein F.M. (Eds). *Proceedings of the Second Workshop on Agglutinated Foraminifera, Vienna 1986. Abhandlungen der Geologishen Bundesanstalt*, **41**, 97-108.

Gradstein, F.M., Kaminski, M.A., Berggren, W.A. & D'iorio, M.A. 1994. Cenozoic biostratigraphy of the Central North Sea and Labrador Shelf. *Micropaleontology*, **40 Supplement**, 1-152.

Gradstein, F.M. & Ogg, J.G. 2004. *A Geologic Time Scale 2004. Cambridge University Press, Cambridge,* 589 pp.

Graham, J.J., de Klasz, I. & Rérat, D. 1965. Quelques importants Foraminifères du Tertiaire du Gabon (Afrique Equatoriale). *Revue de Micropaléontologie*, **8**, 71-84.

Green, R.C., Kaminski, M.A. & Sikora, J.S. 2004. Miocene deep-water agglutinated foraminifera from Viosca Knoll, offshore Louisiana (Gulf of Mexico). *In*: Bubík, M. & Kaminski, M.A. (Eds). Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**, 119-144.

Greenacre, M.J. 1982. Practical correspondence analysis. *In*: Barnett, V. (Ed). *Interpreting Multivariate Data.* Wiley, Chichester, 119-146.

Greenacre, M.J. 1984. Theory and Applications of Correspondence Analysis. Academic Press, London, 364 pp.

Grzybowski, J. 1896. Otwornice czerwonych iłów z Wadowic. *Rozprawy Wydziału Matematyczno-Przyrodniczego, Akademia Umiejętności w Krakowie,* (serya 2), **30**, 261-308.

Grzybowski, J. 1898. Otwornice pokładów naftonosnych okolicy Krosna. *Rozprawy Wydziału Matematyczno-Przyrodniczego, Akademia Umiejętności w Krakowie,* (serya 2), **33**, 257-305.

Grzybowski, J. 1901. Otwornice warstw inoceramowych okolicy Gorlic. *Rozprawy Wydziału Matematyczno-Przyrodniczego, Akademia Umiejętności w Krakowie,* (serya 2), **41**, 219-286.

Hadley, W.H. 1934. Some Tertiary foraminifera from the north coast of Cuba. *Bulletins of American Paleontology*, **20**, 1-41.

Hammer, Ø & Harper, D. 2006. *Paleontological Data Analysis*. Blackwell Publishing, Oxford, 351 pp.

Hammer, Ø, Harper, D. & Ryan, P.D. 2005. PAST: Palaeontological Statistics software package for education and data analysis. *Palaeontologia Electronica*, **4**, 9 pp.

Hantken, M. von 1868. A kis-czelli tályag foraminiferái. *Magyar Foldtani Társulat Munkálatai*, **4**, 75-96.

Hantken, M. von 1875. Die Fauna der Clavulina szaboi-Schichen; Theil I Foraminiferen. *Mittheilungen aus dem Jahrbuche der Koniglich-Ungarische Geologische Anstalt*, **4**, 1-93 + 13 pls.

Haq, B. U., Hardenbol, J., & Vail, P. R. 1987. Chronology of fluctuating sea level since the Triassic. *Science*, **235**, 1136–1167.

Hart, M.B. 1988. Early Miocene agglutinated foraminifera from the Bermuda Abyssal Plain: DSDP Site 603 (NW Atlantic Ocean). *In*: Rögl, F. & Gradstein, F.M. (Eds.) *Second Workshop on Agglutinated Foraminifera, Vienna 1986, Proceedings. Abhandlungen der Geologischen Bundesanstalt*, **41**, 121-131.

Hayek, L.C & Buzas, A.B. 1997. *Surveying Natural Populations*. Columbia University Press, New York, 563 pp.

Hedberg, H.D. 1937. Foraminifera of the Middle Tertiary Carapita Formation of northeastern Venezuela. *Journal of Paleontology*, **8**, 661-697.

Heezen, B.C., Menzies, E., Schneider, E., Ewing, M. & Granelli, N.C. 1964. Congo Submarine Canyon. *Bulletin of the American Association of Petroleum Geologists*, **48**, 1126-1149.

Heron-Allen, E. & Earland, A. 1913. Clare Island survey, Foraminifera. *Proceedings of the Royal Irish Acadamy*, **31**, 1-188.

Hofker, J. 1932. Notizen über die Foraminiferen des Golfes von Neapel, III. Die Foraminiferenfauna der Ammontatura. *Pubblicazione Zoologica di Napoli*, **12**, 61-144.

Holbourn, A., Kuhnt, W., (Toni) Simo, J.A. & Qianyu Li. 2004. Middle Miocene isotope stratigraphy and paleoceanographic evolution of the northwest and southwest Australian margins (Wombat Plateau, Great Australian Bight). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **208**, 1-22.

Holbourn, A., Kuhnt, W., Schulz, M. & Erlenkeuser, H. 2005. Impacts of orbital forcing and atmospheric carbon dioxide on Miocene ice-sheet expansion. *Nature*, **438**, 483-487.

Hornibrook, N. de B. 1961. Tertiary foraminifera from the Oamaru district (N.Z.); Pt. 1-Systematics and distribution. *New Zealand Geological Survey Paleontology Bulletin*, **34**, 192 pp.

Hotelling, H. 1933. Analysis of a complex of statistical variables into principal components. *Journal of Educational Psychology*, **24**, 417-441, 498-520.

Jansen, J.H.F, Van Weering, T.C.E., Gieles, R. & Van Iperen, J. 1984. Middle and Late Quaternary oceanography and climatology of the Zaire-Congo fan and the adjacent eastern Angola basin. *Netherlands Journal of Sea Research*, **17**, 201-249.

Jenkins, D.G. 1967. Planktonic foraminiferal zones and new taxa from the lower Miocene to the Pleistocene of New Zealand. *New Zealand Journal of Geology and Geophysics*, **10**, 1064-1078.

Jenkins, D.G., Saunders, J.B. & Cifelli, R. 1981. The relationship of Globigerinoides bisphericus Todd 1954 to Praeorbulina sicana (de Stefani) 1952. *Journal of Foraminiferal Research*, **11**, 262-267.

Jonasson, K.E., Schröder-Adams, C.J. & Patterson, R.T. 1995. Benthic foraminiferal distribution at Middle Valley, Juan de Fuca Ridge, a northeast Pacific hydrothermal venting site. *Marine Micropaleontology*, **25**, 151-167.

Jones, R.W. 1994. *The Challenger Foraminifera*. Oxford University Press, 149 pp.

Jones, R.W. 1999. Forties Field (North Sea) revisited: a demonstration of the value of historical micropalaeontological data. *In*: Jones, R.W. & Simmons, M.D. (Eds). *Biostratigraphy in Production and Development Geology. Geological Society, London, Special Publications*, **152**, 185-200.

Jones, R.W. 2006. *Applied Palaeontology*. Cambridge University Press, 434 pp.

Jones, R.W., Bender, H., Charnock, M.A., Kaminski, M.A. & Whittaker, J.E. 1993. Emendation of the foraminiferal genus Cribrostomoides Cushman, 1910, and its taxonomic implications. *Journal of Micropalaeontology*, **12**, 181-193.

Jones, R.W. & Charnock, M.A. 1985. "Morphogroups" of agglutinating foraminifera. Their life positions and feeding habits and potential applicability in (paleo)ecological studies. *Revue de Paleobiologie*, **4**, 311-320.

Jones, R.W., Pickering, K.T., Boudagher-Fadel, M. & Matthews, S. 2005. Preliminary observations on the micropalaeontological characterization of submarine fan/channel sub environments, Ainsa System, south-central Pyrenees, Spain. *In*: Powell, A.J. & Riding, J.B. (Eds). *Recent Developments in Applied Biostratigraphy*. Special Publication of the Micropalaeontological Society, **1**, 55-68.

Jones, T.R. & Parker, W.K. 1860. On the Rhizopodal fauna of the Mediterranean compared with that of the Italian and some other Tertiary deposits. *Quarterly Journal of the Geological Society of London*, **16**, 292-307.

Jorissen, F.J. 1999. Benthic foraminiferal succession across Late Quaternary Mediterranean sapropels. *Marine Geology*, **153**, 91-101.

Jorissen, F.J., Barmawidjaja, D.M., Puskaric, S. & Van Der Zwaan, G.J. 1992. Vertical distribution of benthic foraminifera in the northern Adriatic Sea: the relation with the organic flux. *Marine Micropaleontology*, **19**, 131– 146.

Jorissen, F.J., de Stigter, H.C. & Widmark, J.G.V. 1995. A conceptual model explaining benthic foraminiferal microhabitats. *Marine Micropaleontology*, **26**, 3-15.

Kaiho, K. 1991. Global changes of Paleogene aerobic/anaerobic benthic foraminifera and deep-sea circulation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **83**, 65-85.

Kaiho, K. 1994. Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the modern ocean. *Geology*, **22**, 719-722.

Kaiho, K. & Hasegawa, T. 1994. End-Cenomanian benthic foraminiferal extinctions and oceanic dysoxic events in the northern Pacific Ocean. *Paleogeography, Paleoclimatology, Paleoecology*, **111**, 29-43.

Kaminski, M.A. 1985. Evidence for control of abyssal agglutinated foraminiferal community structure by substrate disturbance: Results from the HEBBLE Area. *Marine Geology*, **66**, 113-131.

Kaminski, M.A. 1988. *Cenozoic Deep-water Agglutinated Foraminifera in the North Atlantic.* Unpublished Ph.D. Thesis, WHOI/MIT Joint Program in Oceanography. WHOI 88-3, 262 pp.

Kaminski, M.A. 2004. The year 2000 classification of the agglutinated foraminifera. *In*: Bubík, M. & Kaminski, M.A. (Eds). Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**, 257-271.

Kaminski, M.A. & Austin, W.E.N. 1999. Oligocene Deep Water Agglutinated Foraminifers at Site 985, Norwegian Basin, southern Norwegian Sea. *Proceedings of the Ocean Drilling Program, Scientific Results*, **162**, 169-177.

Kaminski, M.A., Boersma, A., Tyszka, J. & Holbourn, A.E.L. 1995. Response of deep-water agglutinated foraminifera to dysoxic conditions in the California Borderland Basins. *In*: Kaminski, M.A., Geroch, S. & Gasiński, M.A. (Eds). Proceedings of the Fourth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **3**, 131-140.

Kaminski, M.A. & Geroch, S. 1993. A revision of foraminiferal species in the Grzybowski Collection. *In*: Kaminski, M.A., Geroch, S. & Kaminski, D. (Eds). *The Origins of Applied Micropaleontology: The School of Jozef Grzybowski. Grzybowski Foundation Special Publication no. 1*, 239-323.

Kaminski, M.A. & Gradstein, F.M. 2005. Atlas of Paleogene cosmopolitan deep-water agglutinated foraminifera. *Grzybowski Foundation Special Publication*, **10**, 547 + vii pp

Kaminski, M.A., Gradstein, F.M. & Berggren, W.A. 1989. Paleogene benthic Foraminifer biostratigraphy and paleoecology at Site 647, Southern Labrador Sea. *Proceedings of the Ocean Drilling Program, Scientific Results*, **105**, 705-730.

Kaminski, M.A., Gradstein, F.M., Berggren, W.A., Geroch, S. & Beckmann, J.P. 1988. Flysch-type agglutinated foraminiferal assemblages from Trinidad: Taxonomy, Stratigraphy and Paleobathymetry. *In*: Proceedings of the Second Workshop on Agglutinated Foraminifera, Vienna 1986. *Abhandlungen der Geologishen Bundesanstalt*, **41**, 155-228.

Kaminski, M.A., Gradstein, F.M., Goll, R.M. & Grieg, D. 1990. Biostratigraphy and paleoecology of deep-water agglutinated foraminifera at ODP Site 643, Norwegian-Greenland Sea. *In*: Hamleben, C., Kaminski, M.A., Kuhnt, W. & Scott, D.B. (Eds). *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera*, 345-386. NATO ASI Series. Dordrecht: Kluwer Academic Publishers.

Kaminski, M.A. & Huang, Z. 1991. Biostratigraphy of deep-water agglutinated foraminifera at Site 767 (Celebes Sea). *Proceedings of the Ocean Drilling Program, Scientific Results*, **124**, 171-180.

Kaminski, M.A. & Kuhnt, W. 2004. What, if anything, is a *Paratrochamminoides*? A key to the morphology of the Cretaceous to Cenozoic species of *Conglophragmium* and *Paratrochamminoides* (Foraminifera). *In*: Bubík, M. & Kaminski, M.A. (Eds). Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**, 273-285.

Kaminski, M.A., Silye, L. & Kender, S. 2005. Miocene deep-water agglutinated foraminifera from ODP Hole 909c: Implications from the paleoceanography of the Fram Strait Area, Greenland Sea. *Micropaleontology*, **51**, 373-403.

Karner, G.D. & Driscoll, N.W. 1999. Tectonic and stratigraphic development of the west African and eastern Brazilian margins: insights from quantitative basin modelling. *In*: Cameron, N.R., Bate, R.H. & Clure, V.S. (Eds). *The Oil and Gas Habitats of the South Atlantic. Geological Society (London), Special Publication*, **153**, 11-40.

Karner, G.D., Driscoll, N.W., McGinnis, J.P., Brumbaugh, W.D. & Cameron, N.R. 1997. Tectonic significance of syn-rift sediment packages across the Gabon-Cabina continental margin. *Marine and Petroleum Geology*, **14**, 973-1000.

Karrer, F. 1866. Über das auftreten von Foraminiferen in den alteren Schichten des Wiener Sandsteins. (In German). *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften Wein, Mathematisch-Naturwissenschaftliche Klasse*, **52**, 121–193.

Keller, G. & Barron, J.A. 1983. Paleoceanographic implications of Miocene deep-sea hiatuses. *Geology Society of America Bulletin*, **94**, 590-613.

Kender, S., Kaminski, M. A. & Cieszkowski, M., 2005. Foraminifera from the Eocene Variegated Shales near Barwinek (Magura Unit, Outer Carpathians), the type locality of Noth (1912) revisited. *Annales Societatis Geologorum Poloniae*, **75**, 249-272.

Kender, S., Kaminski, M.A. & Jones, B.W. 2006. Four new species of deep-water agglutinated Foraminifera from the Oligocene – Miocene of the Congo Fan (offshore Angola). *Micropaleontology*, **52**, 465-470.

Kender, S., Kaminski, M.A. & Jones, R.W. (In Press). Oligocene deep-water agglutinated foraminifera from the Congo Fan, offshore Angola: Palaeoenvironments and assemblage distributions. *Proceedings of the Seventh International Workshop on Agglutinated Foraminifera, Grzybowski Foundation Special Publication.*

Kennett, J.P. & Srinivasan, M.S. 1983. *Neogene Planktonic Foraminifera. A Phylogenetic Atlas.* Hutchinson Ross, Stroudsburg, P.A., 265 pp.

Koho, K.A., Kouwenhoven, T.J., de Stigter, H.C. & van der Zwaan, G.J. 2007. Benthic foraminifera in the Nazaré canyon, Portuguese continental margin: sedimentary environments and disturbance. *Marine Micropaleontology*, doi: 10.1016/j.marmicro.2007.07.005

Kohl, B. 1985. Early Pliocene benthic foraminifers from the Salina Basin, Southeastern Mexico. *Bulletins of American Palaeontology*, **88**, 1-157.

Krashenninikov, V.A. 1973. Cretaceous benthonic foraminifera, Leg 20, Deep Sea Drilling Project. *Initial Reports of the Deep Sea Drilling Project*, **20**, 205-221.

Kuhnt, W., Hess, S. & Jian, Z. 1999. Quantitative composition of benthic foraminiferal assemblages as a proxy indicator for organic carbon flux rates in the South China Sea. *Marine Geology*, **156**, 123–157

Kuhnt, W., Holbourn, A. & Zhao, Q. 2002. The early history of the South China Sea: evolution of Oligocene-Miocene deep water environments. *Revue de Micropaléontologie*, **45**, 99-159.

Kuhnt, W. & Pletsch, T. 2001. Deep-water environments of the Maastrichtian to Eocene Strait of Gibralter (Djebel Moussa Group, Northern Morrocco). *In*: Bubík, M. & Kaminski, M.A.

(Eds). Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**, 295-316.

Kurihara, K. & Kennett, J.P. 1986. Neogene benthic foraminifers: Distribution in depth transverse, Southwest Pacific. *In* Kennett, J.P., von der Borch, C.C, et al., *Initial Reports DSDP*, **90**, 1037-1077.

Lavier, L.L., Steckler, M.S. & Brigaud, F. 2001. Climate and tectonic control on the Cenozoic evolution of the West African Margin. *Marine Geology*, **178**, 63-80.

Le Calvez, Y. 1977. Révision des Foraminifères de la collection d'Orbigny. II. Foraminifères de l'île de Cuba. *Cahiers de Micropaléontologie*, **2**, 1-131.

Le Calvez, Y., de Klasz, I. & Brun, L. 1971. Nouvelle contribution a al connaissance des microfaunes du Gabon. *Revista Española de Micropaleontología*, **6**, 381-400.

LeRoy, D.O. & Levinson, S.A. 1974. A deep-water Pleistocene microfossil assemblage from a well in the northern Gulf of Mexico. *Micropaleontology*, **21**, 1-37.

LeRoy, L.W. 1939. Some small foraminifera, ostracoda and otoliths from the Neogene ('Miocene') of the Rockan-Tapanoeli area, central Sumatra, *Natuurkunde Tijdschrift Nederlands Indie*, **99**, 215-296.

Licari, L. & Mackensen, A. 2005. Benthic foraminifera off West Africa (1°N to 32°S): Do live assemblages from the topmost sediment reliably record environmental variability? *Marine Micropaleontology*, **55**, 205-233.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata. (Systema Nat. ed. **10**), v. 1, Holmiae (Stockholm), i-ii + 1-824.

Loeblich, A.R. & Tappan, H. 1955. Revision of some Recent foraminiferal genera. *Smithsonian Institute, Miscellaneous Collections*, **128**, 1-37.

Loeblich, A.R. & Tappan, H. 1984. Some new proteinaceous and agglutinated genera of Foraminiferida. *Journal of Paleontology*, **58**, 1158-1163.

Loeblich, A.R. & Tappan, H. 1987. *Foraminiferal Genera and their Classification.* Van Nostrand Reinhold, New York, 2 vols, 1182 pp.

Lourens, L.J., Hilgen, F.J., Laskar, J., Shackleton, N.J., & Wilson, D. 2004. The Neogene Period. *In*: Gradstein, F.M. et al. (Eds.) *A geologic time scale 2004.* Cambridge University Press, Cambridge, p. 409–440.

Łuczkowska, E. 1974. Miliolidae (Foraminiferida) from the Miocene of Poland. Part II: Biostratigraphy, Palaeoecology and Systematics. *Acta Palaeontologica Polonica*, **19**, 3-176.

Lundquist, J.J., Culver, S.J. & Stanley, D.J. 1997. Foraminiferal and lithologic indicators of depositional processes in Wilmington and South Heyes submarine canyons, U.S. Atlantic continental slope. *Journal of Foraminiferal Research*, **27**, 209-231.

Macfadyen, W.A. 1930. Miocene foraminifera from the clysmic area of Egypt and Sinai, with an account of the stratigraphy and a correlation of the local Miocene succession. *Surveys of Egypt-Geological Survey*, **40**, 149 pp.

McLean, J.D. 1956. The foraminifera of the Yorktown formation in the York-James peninsula of Virginia, with notes on the associated molluscs. *Bulletin of American Paleontology*, **36**, 261-394.

McNeil, D.H. 1988. *Cyclammina cyclops*, n. sp., in the Eocene Richards Formation, Beaufort Sea area of Arctic Canada. *Journal of Foraminiferal Research*, **18**, 114-123.

Miller, K.G., Fairbanks, R.G. & Mountain, G.S. 1987. Tertiary oxygen isotope synthesis, sea-level history, and continental margin erosion. *Paleoceanography*, **2**, 1-19.

Miller, K.G, & Katz, M.E. 1987. Oligocene to Miocene benthic foraminiferal and abyssal circulation changes in the North Atlantic. *Micropaleontology*, **33**, 97-149.

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N. & Peckar, S.F. 2005. The Phanerozoic record of global sea-level change. *Science*, **310**, 1293-1298.

Miller, K.G., Wright, J.D. & Fairbanks, R.G. 1991. Unlocking the ice house: Oligocene-Miocene oxygen isotopes, eustacy and margin erosion. *Journal of Geophysical Research*, **96**, 6829-6848.

Mjatliuk, E.V. 1966. K voprosu o foraminiferakh c kremnevnym skeletom [On the question of foraminifera with a siliceous skeleton]. *Voprosy Mikropaleontologii*, **10**, 255-269.

Mjatliuk, E.V. 1970. Foraminifery flishevykh otlozhenii vostochnykh Karpat (Mel-Paleogen) [Foraminifera of the flysch deposits of the eastern Carpathians]. *Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geologorazvedochnogo Instituta VNIGRI*, **282**, 1-225. Leningrad.

Morkhoven, F.P.C.M. Van, Berggren, W.A. & Edwards, A.S. 1986. Cenozoic cosmopolitan deep-sea benthic foraminifera. *Bulletin des Centres des Recherches Exploration-Production Elf-Aquitaine, Memoire* **11**, 421 pp.

Murray, J.W. & Alve, E. 1994. High diversity agglutinated foraminiferal assemblages from the NE Atlantic dissolution experiments. *Cushman Foundation Special Publication*, **32**, 33-51.

Murray, J.W. & Pudsey, C.J. 2004. Living (stained) and dead foraminifera from the newly ice-free Larsen Ice Shelf, Weddell Sea, Antarctica: ecology and taphonomy. *Marine Micropaleontology*, **53**, 67-81.

Mutti, M., Droxler, A.W. & Cunningham, A.D. 2005. Evolution of the Northern Nicaragua Rise during the Oligocene-Miocene: Drowning by environmental factors. *Sedimentary Geology*, **175**, 237-258.

Nagy, J. 1992. Environmental significance of foraminiferal morphogroups in Jurassic North Sea deltas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **95**, 111-134.

Nagy, J. Gradstein, F.M., Kaminski, M.A., Holbourn, A.E.L., 1995. Foraminiferal morphogroups, paleoenvironments and new taxa from Jurassic and Cretaceous strata of Thakkhola, Nepal. *In*: Kaminski, M.A., Geroch, S. & Gasinski, M.A. (Eds.), *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera, Grzybowski Foundation Special Publication* **3**,181-209.

Nagy, J., Kaminski, M.A., Johnsen, K. & Mitlehner, A.G. 1997. Foraminiferal, palynomorph, and diatom biostratigraphy and paleoenvironments of the Torsk Formation: A reference section for the Paleocene-Eocene transition in the western Barents Sea. *In*: Hass, H.C. & Kaminski, M.A. (Eds). *Contributions to the Micropaleontology & Paleoceanography of the Northern North Atlantic. Grzybowski Foundation Special Publication*, **5**, 15-38.

Natland, M.L. 1940. New genus of foraminifera from the later Tertiary of California. *Journal of Paleontology*, **14**, 568-571.

Neugeboren, J.L. 1852. Foraminiferen von Ober-Lapugy; vierter Artikel. *Vereins Naturwiss. Hermannstadt; Verhandlungen, Mitteilungen, Jahrgang*, **3**, 118-123.

Noth, R. 1912. Die Foraminiferenfauna der roten Tone von Barwinek und Karmarnók. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients*, **25**, 1-24 + 1 pl.

Nürnberg, D., & Müller, R. D. 1991. The tectonic evolution of the South Atlantic from Late Jurassic to Present. *Tectonophysics*, **191**, 27-53.

Nuttall, W.L.F. 1928. Tertiary foraminifera from the Naparima region of Trinidad (British West Indies). *Quarterly Journal of the Geological Society of London*, **84**, 57-116.

Ogg, J. & Lugowski, A. 2007. TS-Creator visualisation of enhanced Geologic Time Scale database (Version 3.0). James Ogg (database coordinator) and Adam Lugowski (software developer) http://www.stratigraphy.org and http://www.chronos.org .

Orbigny, A. D', 1826. Tableau méthodique de la classe des cephalopods. *Annales de Science Naturelles, Paris (ser.1)*, **7**, 245-314.

Orbigny, A. D'. 1839. Foraminifères. In: Ramon de la Sagra: *Histoire physique, politique et naturelle de l'île de Cuba*, Arthus Bertrand, Paris, 224 pp.

Orbigny, A. D'. 1846. *Foraminifères fossils du Bassin Tertiairy de Vienne*. Paris: Gide et Comp., Libraires-Editeurs, 312 pp.

Osterman, L. & Spiegler, D. 1996. Agglutinated benthic foraminiferal biostratigraphy of Ocean Drilling Program (ODP) Sites 909 and 913, northern North Atlantic. *Proceedings of the Ocean Drilling Program, Scientific Results*, **151**, 169-185.

Pagani, M., Authur, M.A. & Freeman, K.H. 1999. Miocene evolution of atmospheric carbon dioxide. *Paleoceanography*, **14**, 273-292.

Palmer, D.K. 1941. Foraminifera of the Upper Oligocene Cojimar Formation of Cuba, Part 4. *Sociedad Cubana de Historia Natural "Felipe Poey", Memorias*, **15**, 181-200.

Palmer, D.K. & Bermúdez, P.J. 1936. An Oligocene foraminiferal fauna from Cuba. Part 2. *Sociedad Cubana de Historia Natural "Felipe Poey", Memorias*, **10**, 227-317.

Papp, A. & Schmid, M.E. 1985. Die fossilen Foraminiferen des tertiären Beckens von Wien. Revision der Monographie von Alcide d'Orbigny (1846). *Abhandlungen der Geologischen Bundesanstalt*, Wien, **37**, 107 pp.

Papp, A. & Turnovsky, K. 1953. Die Entwicklung der Uvigerinen im Vindobon (Helvet und Torton) des Wiener Beckens. *Jahrbuch des Geologischen Bundesanstalt*, **96**, 117-142.

Parker, F.L. 1952. Foraminiferal species off Portsmouth, New Hampshire. *Bulletin of the Museum of Comparative Zoology*, **106**, 391-423 + 6 pls.

Parr, W.J. 1950. Part 6, Foraminifera. *B.A.N.Z. Antarctic Research Expedition 1929-1931 Reports*, Series B (Zoology and Botany), **5** (6), 237-392.

Pekar, F.P., DeConto, R.M. & Harwood, D.M. 2006. Resolving a late Oligocene conundrum: Deep-sea warming and Antarctic glaciation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **231**, 29-40.

Persico, D. & Villa, G. 2004. Eocene-Oligocene calcareous nannofossils from Maud Rise and Kerguelen Plateau (Antarctica): paleoecological and paleoceanographic implications. *Marine Micropaleontology*, **52**, 153-179.

Petters, S.W. 1982. Central West African Cretaceous-Tertiary benthic foraminifera and stratigraphy. *Palaeontographica, Abt. A*, **179**, 1-104.

Phleger, F.B. & Parker, F.L. 1951. Ecology of foraminifera of northwest Gulf of Mexico. *Geological Society of America Memoir*, **46**, 1-64.

Picou, E. B., Jr., Perkins, B. F., Rosen, N. C. & Nault, M. J. (Eds.) 1999. *Gulf of Mexico basin biostratigraphic index microfossils - a geoscientist's guide: foraminifers and nannofossils, parts I and II, Oligocene through Pleistocene foraminifers.* Gulf Coast Society of Economic Paleontologists and Mineralogists Foundation, 215 pp., 3 charts, 2 tables of synonyms (Text and CD-ROM).

Prebble, J.G., Raine, J.I., Barrett, P.J. & Hannah, M.J. 2006. Vegetation and climate from two Oligocene glacioeustatic sedimentary cycles (31 and 24 Ma) cored by the Cape Roberts

Project, Victoria Land Basin, Antarctica. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **231**, 41-57.

Preece, R.C. 1999. *The physiological response of equatorial Neogene bathyal benthic foraminifera to low oxygen conditions*. Unpublished Ph.D. Thesis, University of London, 375 pp. + 84 pl.

Preece, R.C., Kaminski, M.A. & Dignes, T.W. 1999. Miocene benthonic foraminiferal morphogroups in an oxygen minimum zone, offshore Cabinda. *In*: Cameron, N.R., Bate, R.H. & Clure, V.S. (Eds). *The Oil and Gas Habitats of the South Atlantic. Geological Society (London), Special Publication*, **153**, 267-282.

Preece, R.C., Kaminski, M.A. & Dignes, T.W. 2000. Popovia johnrolandi n.sp., a new smaller agglutinated foraminifera from northern Venezuela: a biostratigraphical example of the second law of thermodynamics. *In*: Hart, M.B., Kaminski, M.A., & Smart, C.W. (Eds). *Proceedings of the Fifth International Workshop on Agglutinated Foraminifera. Grzybowski Foundation Special Publication*, **7**, 403-410.

Renz, H.H. 1948. Stratigraphy and fauna of the Agua Salada Group, State of Falcon, Venezuela. *Memoirs of the Geological Society of America*, **32**, 219 pp.

Reuss, A.E. 1845. *Die Versteinerungen der böhmischen Kreideformation*. Abtheilung 1. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, iv + 58 pp.

Reuss, A.E. 1850. Neue Foraminiferen aus den Schichten des Oesterreichischen Teriärbeckens. *Denkschriften der Akademie der Wissenschaften, Wien,* (Math.-Natw. Cl., **1**), 365-390.

Reuss, A.E. 1851. Die Foraminiferen und Entomostraceen des Kreidemergels von Lemberg. *Naturwissenschaftliche Abhandlungen, Wien*, **4**, 15-52.

Reuss, A.E. 1866. Die Foraminiferen, Anthozoen und Bryozoen des deutschen Septarienthones. *Denkschrift der Kaiserlichen Akademie der Wissenschaften, Wien*, (Math.-Natw. Cl., **25**), 1-129.

Reuss, A.E. 1867. Die fossile Fauna der Steinslazlagerung von Wieliczka in Galizien. *Sitzungsberichte der Kaiserlichen Akadamie der Wissenschaften, Wien.* (Math.-Natw., Cl.), **55** (1), 17-182.

Rhumbler, L. 1905. Mitteilungen über Foraminiferen (mit Demonstrationen). *Verhandlungen der Deutchen Zoologischen Gesellschaft*, **15**, 97-106.

Roberts, A.P., Wilson, G.S., Harwood, D.M. & Verosub, K.L. 2003. Glaciation across the Oligocene-Miocene boundary in southern McMurdo Sound, Antarctica: new chronology from the CIROS-1 drill hole. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **198**, 113-130.

Robertson, B.E. 1998. Systematics and paleoecology of the benthic Foraminiferida from the Buff Bay section, Miocene of Jamaica. *Micropaleontology*, 44, 266 pp.

Robertson, D. 1891. Trochammina Bradyi, n.n. *Annals and Magazine of Natural History*, 7, 388.

Rogerson, M., Kouwenhoven, T.J., van der Zwaan, G.J., O'Neill, B.J., van der Zwan, C.J., Postma, G., Kleverlaan, K. & Tijbosch, H. 2006. Benthic foraminifera of a Miocene canyon and fan. *Marine Micropaleontology*, **60**, 295-318.

Rögl, F. 1995. A Late Cretaceous flysch-type agglutinated foraminiferal fauna from the Trochamminoides proteus type locality (Wien - Hütteldorf, Austria) *In*: Kaminski, M.A., Geroch, S. & Gasinski, M.A. (Eds). *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera. Grzybowski Foundation Special Publication*, **3**, 249-263.

Rögl, F. & Hansen, H.J. 1984, Foraminifera described by Fichtel and Moll in 1798: a revision of Testacea Microscopica. *Neue Denk-Schriften des Naturhistorischen Museums Wien*, **3**, 1-143.

Samuel, O. 1977. Agglutinated foraminifers from Paleogene flysch formations in West Carpathians of Slovakia. *Zapadne Karpaty, serie paleontologie*, **2-3**, 7-70.

Săndulescu, J. 1972. Étude micropaléontologique et stratigraphique du flysch du Crétacé Supérieur-Paléocène de la région de Brețcu-Comandău (Secteur Interne Méridional de la Nappe de Tarcău-Carpates Orientales). *Mémoires, Institut Geologique, Bucureşti*, **17**, 52 pp. + 16 pl.

Sars, G.O. 1872. Undersøgelser over Hardangerfjordens Fauna. *Forhandlinger i Videnskasselskabet i Kristiania, 1871*, 246-255.

Saunders, J.B., Bernoulli, D., Müller-Merz, E., Oberhänsli, H., Perch-Nielsen, K., Riedel, W.R., Sanfilippo, A. & Torrini, R. jr. 1984. Stratigraphy of the later Middle Eocene to Early Oligocene in the Bath Cliff section, Barbados, West Indies. *Micropaleontology*, **30**, 390-425.

Savoye, B, Cochonat, P., Apprioual, R., Bain, O., Baltzar, A., *et al.* 2000. Structure et evolution récente de l'éventail turbiditique du Zaïre: premiers résultats scientifiques des missions d'exploration Zaïango 1 & 2 (marge Congo-Angola). *Comptes-Rendus l'Académie des Sciences de la Terre et des Planétes*, **331**, 211-220.

Schijfsma, E. 1946. The foraminifera from the Hervian (Campanian) of southern Limburg. *Mededelingen Geologische Stichting C-V-7*, 174 pp.

Schmiedl, G., Mackensen, A. & Müller, P.J. 1997. Recent benthic foraminifera from the eastern South Atlantic Ocean: Dependence on food supply and water masses. Marine *Micropaleontology*, **32**, 249-287.

Schnitker, D. 1980. North Atlantic oceanography as possible cause of Antarctic glaciation and eutrophication. *Nature*, **284**, 615-616.

Schröder, C.J. 1896. Changes in benthic foraminifer assemblages across the Holocene/Pleistocene boundary, Sites 619, 620, 621, 622, and 624. Deep Sea Drilling Project 96. *Initial Reports of the Ocean Drilling Project*, **94**, 631-642.

Schröder, C.J., Scott, D.B., Medioli, F.S., Bernstein, B.B. & Hessler, R.R. 1988. Larger agglutinated foraminifera: comparison of assemblages from Central North Pacific and Western North Atlantic (Nares Abyssal Plain). *Journal of Foraminiferal Research*, **18**, 25-41.

Schultze, F.E. 1875. *Zoologische Ergebnisse der Nordseefart vom 21 Juli bis 9 September 1872; 1. Rhizopoden.* Commission der Wissenschaftliche Untersuchung Deutschlands Meere von Kiel, Jahresberichte. Berlin, Deutschland, 1875, Jahrg. 2-3.

Schumacher, S., Jorissen, F.J., Dissard, D., Larkin, K.E. & Gooday, A.J. 2007. Live (Rose Bengal stained) and dead benthic foraminifera from the oxygen minimum zone of the Pakistan continental margin (Arabian Sea). *Marine Micropaleontology*, **62**, 45-73.

Schwager, C. 1866. Fossile Foraminiferen von Kar Nikobar. *Novara Expedition 1857-1859. Wien, Geologischer Theil*, **2**, 187-268.

Seiglie, G.A. & Baker, M.B. 1983. Some West African Cenozoic agglutinated foraminifers with inner structures: taxonomy, age and evolution. *Micropaleontology*, **29**, 391-403.

Séranne, M. & Abeigne, C.N. 1999. Oligocene to Holocene sediment drifts and bottom currents on the slope of Gabon continental margin (west Africa). Consequences for sedimentation and southeast Atlantic upwelling. *Sedimentary Geology*, 128, 179-199.

Séranne, M. & Anka, Z. 2005. South Atlantic continental margins of Africa: A comparison of the tectonic vs climate interplay on the evolution of west Africa and SW Africa margins. *Journal of African Earth Sciences*, **43**, 283-300.

Shackleton, N.J. 1974. Attainment of isotopic equilibrium between ocean water and the benthonic foraminifera genus *Uvigerina*: Isotopic changes in the ocean during the last glacial. *Coloques Internationaux du C.N.R.S.*, **219**, 203-209.

Smart, C.W. 2002. Environmental applications of deep-sea benthic foraminifera. *In*: Haslett, S. K. (Ed.), *Quaternary Environmental Micropalaeontology,* Arnold, London, 14-58.

Smith. A.J & Gallagher, S.J. 2003. The Recent foraminifera and facies of the Bass Canyon: a temperate submarine canyon in Gippsland, Australia. *Journal of Micropalaeontology*, **22**, 63-84.

Smith, D.J. 1948. Miocene foraminifera of the "Harang sediments" of southern Louisiana. *Bulletin of the Louisiana Geological Survey*, **26**, 23-80.

Smith, L.I. 2002. A tutorial on Principal Components Analysis. University of Otago. http://csnet.otago.ac.nz/cosc453/student_tutorials/principal_components.pdf

Spezzaferri, S. 1994. Planktonic foraminiferal biostratigraphy and taxonomy of the Oligocene and lower Miocene in the oceanic record. An overview. *Paleontographia Italica*, **81**, 1-187.

Stankiewicz, J. & de Wit, M.J. 2006. A proposed drainage model for Central Africa – Did the Congo flow east? *Journal of African Earth Sciences*, **44**, 75-84.

Stewart, R.E. & Stewart, K.C. 1930. Post-Miocene foraminifera from the Ventura Quadrangle, Ventura Co., California. *Journal of Paleontology*, **4**, 60-72.

Stuut, J.B., Prins, M.A., Schneider, R.R., Weltje, G.J., Jansen, J.H.F. & Postma, G. 2002. A 300 kyr record of aridity and wind strength in Southwestern Africa: inferences from grain-size distributions of sediments on Walvis Ridge, SE Atlantic Ocean. *Marine Geology*, **180**, 221–233.

Sultan, N., Cochonat, P., Cayocca, F., Bourillet, J.-F. & Colliat, J.-L. 2004. Analysis of slumping in the Gabon continental slope. *AAPG Bulletin*, **88**, 781-799.

Teil, H. 1975. Correspondence factor analysis: An outline of its method. *Mathematical Geology*, **7**, 3-12.

Todd, R. 1954. Appendix in: Todd, R., Cloud, P.E. Jr., Low, D. & Schmidt, R.G. Probable occurrence of Oligocene on Saipan. *American Journal of Science*, **252**, 673-682.

Tucholke, B.E. 1979. Relationships between acoustic stratigraphy and lithostratigraphy in the Western North Atlantic Basin. *In*: Tucholke, B.E., Vogt, P.R. *et al.* 1979. *Initial Reports of the Deep Sea Drilling Project, v. 43: Washington (U.S. Government Printing Office)*, 827-846.

Tucholke, B.E. & Mountain, G.S. 1986. Tertiary paleoceanography of the western North Atlantic Ocean. *In*: Tucholke, B. E. & Vogt, P. R. (Eds) *The Geology of North America, volume M, The Western North Atlantic Region,* Geological Society of America, Boulder, 631–650.

Uenzelmann-Neben, G. 1998. Neogene sedimentation history of the Congo Fan. *Marine and Petroleum Geology*, **15**, 635-650.

Uenzelmann-Neben, G., Spiess, V. & Bleil, U. 1997. A seismic reconnaissance survey of the northern Congo Fan. *Marine Geology*, **140**, 283-306.

Ufkes, E., Jansen, J.H.F. & Schneider, R.R. 2000. Anomalous occurrences of Neogloboquadrina pachyderma (left) in a 420-ky upwelling record from Walvis Ridge (SE Atlantic). *Marine Micropaleontology*, **40**, 23-42.

Van den Akker, T.J.H.A., Kaminski, M.A., Gradstein, F.M. & Wood, J. 2000. Campanian to Palaeocene biostratigraphy and palaeoenvironments in the Foula Sub-basin, west of the Shetland Islands, UK. *Journal of Micropalaeontology*, **19**, 23-43.

Van der Zwaan, G.J., Duijnstee, I.A.P., den Dulk, M., Ernst, S.R., Jannink, N.T. & Kouwenhoven, T.J. 1999. Benthic foraminifers: proxies or problems? A review of paleocological concepts. *Earth-Science Reviews*, **46**, 213-236.

Van der Zwaan, G.J., Jorissen, F.J., Verhallen, P.J.J.M. & Von Daniels, C.H. 1986. Atlantic-European Oligocene to recent Uvigerina: taxonomy, paleoecology and paleobiogeography. *Utrecht Micropaleontological Bulletins*, **35**, 240 pp.

Verdenius J.G. & Hinte J.E. 1981. Central Norwegian-Greenland Sea: Tertiary arenaceous foraminifera, biostratigraphy and environment. *Proceedings of the First Workshop Arenenaceous Foraminifera, 7-9 Sept. 1981. Continental Shelf Institute Publication*, **108**, 173-224.

Villa, G. & Persico, D. 2005. Late Oligocene climate changes: Evidence from calcareous nannofossils at Kerguelen Plateau Site 748 (Southern Ocean). *Paleogeography, Paleoclimatology, Paleoecology*, **231**, 110-119.

Vincent, E., and Berger, W.H., 1985. Carbon dioxide and polar cooling in the Miocene: the Monterey hypothesis. *In* Sundquist, E.T., and Broecker, W.S. (Eds.), *The Carbon Cycle and Atmospheric CO2: Natural Variations Archean to Present,* Geophysical Monograph 32, 455-468.

Volat, J.L., Hugo, B. & Bignoumba-Ilogue, J. 1996. Foraminifères arénacés du Crétacé supérieur du Gabon. *Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine*, **20**, 229-275.

Voloshinova, N.A. & Budasheva, A.I. 1961. Lituolids and trochamminids from the Tertiary deposits of Sakhalin Island and the Kamchatka Peninsula (in Russian). *In*: Microfauna of the USSR. *Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geologorazvedochnogo Instituta VNIGRI*, **170**, 170-272. Leningrad.

Walgenwitz, F., Pagel, M., Meyer, A., Maluski, H. & Monié, P. 1990. Thermo-chronological approach to reservoir diagnosis of the offshore Angola basin: a fluid inclusion, 40Ar–39Ar and K–Ar investigation. *AAPG Bulletin*, **74**(5), 547-563.

Walgenwitz, F., Richert, J.P. & Carpentier, P. 1992. Southwest border of African plate; thermal history and geodynamical implications. *In*: Poag, C.W. & de Graciansky, P.C. (Eds). *Geologic Evolution of Atlantic Continental Rises. Van Nostrand Reinhold, New York*, pp. 20-45.

White, M.P. 1928. Some index foraminifera of the Tampico Embayment area of Mexico (Part 2). *Journal of Paleontology*, **2**, 280-317.

Whittaker, J.E. 1988. Benthic Cenozoic foraminifera from Ecuador. Taxonomy and distribution of smaller benthic foraminifera from Coastal Ecuador (Late Oligocene – Late Pliocene). *British Museum (Natural History)*, 194 pp.

Williams, C.B. 1943. Area and number of species. *Nature*, **152**, 264-267.

Wood, K.C., Miller, K.G. & Lohmann, G.P. 1985. Middle Eocene to Oligocene benthic foraminifera from the Oceanic Formation, Barbados. *Micropaleontology*, **31**, 181-197.

Woodruff, F. & Savin, S.M. 1989. Miocene deepwater oceanography. *Paleoceanography*, **4**, 87-140.

Woodruff, F. & Savin, S.M. 1991. Mid-Miocene Isotope Stratigraphy in the Deep Sea: High-Resolution Correlations, Paleoclimatic Cycles, and Sediment Preservation. *Paleoceanography*, **6**, 755-806.

Wright, J.D., Miller, K.G. & Fairbanks, R.G. 1992. Early and middle Miocene stable isotopes: implications for deepwater circulation and climate. *Paleoceanography*, **7**, 357-389.

Zachos, J., Pagani, M., Sloan, L., Thomas, E. & Billups, K. 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science*, **292**, 686-693.

Zheng, S. & Fu, Z. 2001. Fauna Sinica, Phylum Granuloreticulosa, Class Foraminiferea, Agglutinated Foraminifera. *Science Press, Beijing*, 788 pp. + 122 pls.

PLUTAO-1 - MIOCENE

Depth (m)	No. species	No. specimens	Unidentified agglut.	Unidentified calc.	Rhabdammina spp.	Rhabdammina linearis	Glomospira gordialis	Trochammina spp.	Cyclammina spp.	Ketenopsis spp.	Bathysiphon spp.	Glomospira charoides	Glomospira irregularis	Hormosina globulifera	Subreophax scalaris	Saccammina spp.	Saccammina cf. sphaerica	Reophax pilulifer	Hormosina globulifera	Portatrochammina profunda	Haplophragmoides horridus	Ammodiscus cretaceus	Reticulophragmium spp.	Cribrostomoides subglobosus	Reticulophragmium amplectens	Karrerulina apiculata	Eggerelloides sp.1	Ammosphaeroidina spp.	Paratrochamminoides challengeri	Ammodiscus aff. peruvianus	Paratrochamminoides sp.1	Paratrochamminoides heteromorphus	Conglophragmium irregulare	Rhabdammina cylindrica	Tolypammina spp.	Hyperammina elongata	Cribrostomoides sp.1	Recurvoides azuaensis	Reticulophragmium aff. orbiculare	Trochammina sp.2	Recurvoides spp.	Haplophragmoides spp.	Trochammina sp.1	Paratrochamminoides spp.	Nothia spp.	Haplophragmoides cf. bradyi
2760	1	1			1																																							
2770	7	51			10	3	12	8	4	3	17																																	
2780	7	15	1				4				3	3	1																															
2790	7	14	1		8		3		1					1																														
2800	4	26	6		5		11								1	3																											
2810	51	249	23		48		14	1	1		25	9	6		5		7	3	7	1	6	3	3	1	6	3	1	3	1		3	1	1	7	8	1	1	2	1	1	1	1	1	1	4
2820	14	105	9		3		16		1		28	7	16				9		2			6	1	6										16										
2830	17	123	16				16	5	3		43	2					16		2		1	2											1	8										
2840	43	330	9		10		13	4			28	8					9		3		2	1	1					4						7	2						1		4	3		1
2850	24	186	6		9		48		1		36	4	21				6		5		2							1							6						2			3	
2860	22	161	11		9		42			1	44	10	6		3		3																	5	2					2		1		2
2870	23	121	6				33				11		2	2					5					1	1	1								6	2			1	1	5	1		2	3
2880	17	65					16		2		7	4	3	2	1		4																								2		2	4	
2890	30	278		16	5						1	2		2			2		2			2															1				2	2				
2900	44	280	9	1			12		4		28	4	16		7		5		1		3					1		1	1					16	12			4			1	3			10	
2910	23	284		2			3				5																						1	3										
2920	23	284																																											
2930	23	425	1	2								2																																
2940	24	393	2	3			1				1								2																									
2950	19	481		1							3																														1				
2960	20	125		1	4		1					1																															4		
2970	10	87										1																																	
2980	20	94	4		1							1																						3						1	2				
2990	22	109	2				1				1	1					1					1				1											1						1	13		
3000	11	48	2		1						1		1				1																									1				
3010	38	448	15		4	2	12				18	11	1		2		12		3		2			1				16	2													1	2	1	1	7
3020	33	382	11	3	1		21				27	10	5	2	5		17				2		3		3		1	2	1					12							2		1	4	
3030	43	304	1		23		25				86	19	7		2		12		1		6				3	2		2						6	2			2						7	5
3040	49	253	3	1			12			6	42	18	5	2	5		18		1		2	2	6			2		2		4			1	4		1		1				2	3	2	15	3
3050	58	441		2			7		2		26		2				2			3	2					1				2					1	1		1				1				
3060	49	310			25		8					5	3		4		2				2					1					1			3			1				1				
3070	53	772	10	8	10		3					3		2					3						2																	2		21		
3080	58	316			16		4		1			7	1		3	1	7			2		1				2							1	1	8	7						1	3	2	9	6
3090	53	227	9				3				14			2	4		1	3	8	2						1									9	8					1	1	10	1	12	9
3100	55	270	6				7					11	4	1	2			1	2			3				3									6	6									31	6
3110	53	187	4									4	2		1		3		4			2	1			6	1								6	6			3							
3120	62	325	1	3	19				1			4		1	7		6		5			2	1			1					2				5	2			1		3		4	1	10	
3130	58	293	2				1		1			2			3		1								3	1	1				2					10			1					3	7	
3140	66	400	9	3			11				3	3			1		2		1	4	1	1	1		1								2	13	4								1		21	
3150	51	225	7	2	4		7				3	5	2		1		3	1	2	2			1				2								1	20			1				4			
3160	53	247	16	1	11		9					2	5	2	5		3										4							1	9	1			1				2	1	4		1
3170	62	268	6	1	3		17				1	7	2		5		7					2	1	1	2									2		8	3		1				1	6	8	
3180	50	280	15		9		2		1			6	5		5				3			1		1	3			1								18			1	1					8	
3190	60	188	9		6		3		4			2	3		4		4		6					1		3								7	8			2		3		5	1	4	4
3200	54	280	4				17					4	3		5				7						2										19	11			1					3	5	5
3210	48	226	16		6		13	1			3	1	10	1	5		11																	8	15						7				
3220	53	283	16		16		8	1			2	9	4		3		13		5				2		1								2	4	9						2		80	
3230	60	282	25		10		5		2		9	10	7		1		9		10		3			4		4			1		2			6	21					1	1	8		5	1
3240	32	150	5				8				27	4	3				7		1			1									1			2	7			1				5	1	35	3
3250	31	95	4				10	2			3		1				5					2												5	5							2	1	7	
3260	22	86	5		4		4	3				2	3		1		4								1									5				1						5	
3270	21	59	1			1	2	1			14	1	1		2		4					2												2	1									12	
3280	23	72	3				5					3			1		5														1			2	4						1			5	
3290	22	91	3		12		6					3	5		2		7								1									7	5						1			7	1
3300	30	130			16		8				22	2	1		3		1	1	1							1								1	5			2						22	
3310	28	159	4		17		2	9					5				9							1	4	4								11	10			14			3		1		16	
3320	24	111			18		2					2	5		2		2			1		1												14	7									11	
3330	30	135	3		2		1		1		31	1	1		1		2							1		1								18							1	4	7	
3340	20	121	2		18		8					3	3				9	1																12							1		9	
3350	25	48	3				1						6												1									2									1	
3360	13	38	8		2		1	3			1	2																												1	2			5	
3370	16	83	9				3				18	1	1		1																		2	3										
3380	11	27	1		4							1										1												4									2		
3390	9	17										2	1																					2							3			3	
3410	36	400	5		1		12				25	16	12		7		9		3					3		1							1	6							3	8		46	

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Depth (m)	Paratrochamminoides diazwebbi	Reticulophragmium glassensis	Psammosphaera cf. fusca	Haplophragmoides carinatus	Ammodiscus latus	Reophanus aff. berggreni	Reticulophragmium acutidorsatum	Paratrochamminoides gryzbylskiformis	Rhizammina spp.	Saccammina sp.1	Psammosphaera spp.	Ammodiscus gracilis	Reticulophragmium sp.1	Reticulophragmium rotundidorsatum	Cyclammina cancellata	Buttelinaveolata multicameratа	Reticulophragmium amplectens sp.1	Cribrostomoides spp.	Usbaspiral form	Ammodiscus spp.	Kamurella spp.	Glomospira glomerata	Trochamminoides subcoronatus	Valvulina fimbis	Hyperammina spp.	Pseudonodosinella nodulosa	Nodtia exoleta	Glomospira spp.	Psammosphaera sp.1	Recurvoides sp.1	Eggerella brady	Ammodiscus sp.3	Labutubs lituiformis	Praesphaeramina spp.	Hormosinelloides gallitzi	Discamminoides sp.1	Paratrochamminoides deflexiformis	Haplophragmoides rotulicus	Trochammina sp.3	Ammolagena clavata	Rhabdammina sp.1	Paratrochamminoides nitratus	Cyclammina cancellata ssp.1	Ammosphaeroidina pseudopauciloculata	Nodtia robusta	Kamurella micrograndiosa	Glomospira sp.2	Cyclammina sp.1
2760																																															
2770																																															
2780																																														
2790																																														
2800																																														
2810																																														
2820	1	1																																												
2830			2	2	1	2	1	1																																						
2840	2		6	3			2		4	1	1																																			
2850							1		20			2	5	1	2	1	1																												
2860				1			1		4				6	4	1		1	1	2																										
2870				1					27				9				1	2		1	1																										
2880			1		1				11	1					1							1																									
2890									2														7	1	1																					
2900							1		9				9	4										4			1	1	18																	
2910															1																															
2920																																														
2930												1					1								1																					
2940																													1																	
2950							1																																							
2960				1						1				1															1	1																
2970									1																																					
2980									1																				4			1	1													
2990				1					9				1																2																	
3000																																														
3010							2		36				5										2	1	1							2	1	1	1									
3020			5				2							3							2			1				89						4		1	1							
3030								1	1	5			11	7				1						2	4				21									2	1	19	2	11	1	1			
3040			2				1			5					1			1			1			1	2													2		15		36		1	1		
3050			3		4					1					1														7				1							4		6		1		1	
3060		1	2		2					2					1														17										3	6		14		1		1	
3070		1	6	2			2		7					4										1	1																		3		4		1
3080			2	2			2		15					9	1								3	6								3					1		7	1	7			6	3			
3090			2	1	1	1			11				1		2										5			35											2	1				1			
3100			22		2		1		14	1					1										1	1		10				1							14	1				16	1		
3110										2			1												1			9									3		10	3			1				
3120		1		2					12																1	1		17			3												3			1
3130					3				4	1																			2			1									3		1		1		
3140			4		4		1		5													4																			8		5		1			
3150			2	2					4	3				4						1					1	1						1									1	12			4			
3160			4	2			2		9													1								4			1									3					
3170			5		2				19									1				3						8				2		2					10	1						
3180			14	1	4		1		56																												1			11				4		1	
3190			6	1	4		2		5	4				2								1															1		1	1				2			
3200			18						18	5		2	1	2								6						32				1							5	1				1		
3210			7		3		2		11	3																					2						1	4		6						
3220			2		9		2			6		1		1								1			1				1		3					1		5				2				
3230			5		8		3		3			1	1	1						1					1						1							11		13			8			
3240			2	1	6				9								1											1												3			2			
3250		1	3		4		1		13			1											1																		7			1			
3260			2		1				20						1													1																		
3270		1								1																		2																		
3280			6	1	2				13	1																		6												4						
3290			1		1				7																															7			1			
3300		1	7		4				18	2		2		1														3										2		2			1			
3310		3	2		9	1						9																11				2						7		2						
3320		3	2		9		1		4																															1	12		7					
3330			4	1	9		3		9																			16											2		4	4		1			
3340		2	3				6		20								1																2							7						
3350	1		2		4		8	1	1			3	1												1			2	1												1		1			
3360			3				1		5																																	3					
3370			1		6		1																																			4				
3380		1					2		3																																	1		3			
3390					1		3																					1																	
3410							8										1						3					8										6		1	3					

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Depth (m)	No. species	No. specimens	Nodria robusta	Kamerlella microgranulosa	Glomospira sp.2	Cyclammina sp.1	Valvulina miocenica	Trochamminoides folius	Glomospira sp.1	Gaudryina atlantica	Glomospira aff. serpens	Cyclammina sp.2	Praesphaeroidina sp.1	Hormosinella carpenteri	Dorothia brevis	Kamerlella aff. bradyi	Martinottiella spp.	Bigenerina spp.	Martinottiella aff. communis	Spiroplectammina primula	Trochamminoides spp.	Ammodiscus globratus	Subreophax sp.1	Nodria tallasina	Bulbobaculites sp.1	Reophax spp.	Glaphyrammina americana	Haplophragmoides sp.1	Reticulophragmium acutidorsatum sp.1	Textularia earlandi	Trochammina sp.4	Quinqueloculina tricarinelliformis	Bolivina alazanensis	Obscuroides mundulus	Pyrgo spp.	Hanzawaia mantaensis	Bulimina tuboniensis	Bulimina marginata	Obscuroides spp.	Gyroidinoides altiformis	Gyroidina orbicularis	Globocassidulina subglobosa	Siphonomalia adophina	Pygmaeoseistron spp.	Valvulineria pseudotumeyensis
2760	1	1																																									
2770	7	51																																										
2780	7	15																														1	1	1										
2790	7	14																																	1	1									
2800	4	26																																										
2810	51	249																																4			1		1	1	1	2	1	1	1	7
2820	14	105																																										
2830	17	123																																										
2840	43	330																																3	9			4	16			1		2		2
2850	24	186																																1										
2860	22	161																																										
2870	23	121																																										
2880	17	65																																										
2890	30	278																																37	14				3						144
2900	44	280																																16	8		1		2	1		2				5
2910	23	284																														1	116	13		3			34	2	12					33
2920	23	284																														1	13	12					12		8					197
2930	23	425																																12	5					6	40						11
2940	24	393																																91	1					2	16						6
2950	19	481																																3	1		1				71						
2960	20	125																																7	2				1		3	1					4
2970	10	87																																2	1						3						4
2980	20	94																																	1						6						7
2990	22	109																																2	1						7						9
3000	11	48																																												2
3010	38	448																																108	1						34						1
3020	33	382																																3							17						
3030	43	304																																1	3						1						1
3040	49	253	1																																7							1	2	1		1		
3050	56	441		1																														10	2		26		3		107			3	1		3
3060	49	310			1																													6	2		1	1		4	3	2		2			6
3070	53	772		4			1																											66			88		27	5	124	22			3		7
3080	66	316	3					1	1																													17		1		18	3	3	2			
3090	55	227							1																													4				4				1	4	
3100	55	270	1							3	1	1	2																									5					1	2	2			1
3110	53	187								3																												12		5		5						1
3120	62	325					1			2	1			1	1	1																					9		2	17	1	3		17	2				
3130	58	293		1						1							2																					5	5		20	1	5		7	1	2			
3140	66	400		1						2								1	1																			5			25		3		15	3	3	4	1	1	1
3150	51	225								2																												1			11				11						
3160	53	247																																			5	3		6		3		18		2	2	1		
3170	62	288								2		1						1																				5			8		4		6			2	4		1
3180	50	280	4		1					1			1																								9	6		3		4		8				3		
3190	60	188		2			1														1	1																9		2		4		2	1				
3200	54	280		1			1																1															4	1		7		2			1		3	2		
3210	48	226					1			1																												5	3		4	1	1						2		
3220	53	283																			1		1	4														3			2		1		1					
3230	60	282	5																					9	1													1	1		2		1		4	2				
3240	32	150	2							2																													2										
3250	31	95		1						3																													3		1				1					
3260	22	86																																															
3270	21	59																																									2	1					
3280	23	72																																	2		1										
3290	22	91																																	2												
3300	30	130		1																																							1					
3310	28	159																								2	1							1													
3320	24	111																										1						1	4												
3330	30	135																1											1					2	4												
3340	20	121																					8					3							3								1					
3350	25	48																													1	1		1													
3360	13	38														1																																
3370	16	83	4																					7										27	5												1
3380	11	27	3																																4												
3390	9	17																																	1												
3410	36	400																			1														4						4						

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Depth (m)	No. species	No. specimens	Cassidulina spp.	Nonion sp.1	Cassidulinella pliocenica	Planulina ranzi	Magasotomella africana	Gyroidina umbonata	Bulimina elongata	Uvigerina aff. campiana	Bricalina cf. barbata	Uvigerina hispida	Bricalina aff. inflata	Glandulina ovula	Obiculoides pachyderma	Lenticulina calcar	Obiculoides crebbsi	Hoeglundina elegans	Bulimella sp.1	Chrysalogonium sp.1	Hanzawaia sp.1	Pullenia bulloides	Praeglobobulimina ovata	Siphotextularia subspinosa	Obiculoides havanaensis	Gyroidinoides soldanii	Melonis pompilioides	Amphimorphina stainforthi	Lenticulina americana	Pyrgo nasacaudata	Bulimina mexicana	Lenticulina spp.	Siphonodosaria aff. abyssorum	Siphotextularia spp.	Uvigerina mediterranea	Hanzawaia spp.	Anomalinoides spp.	Neoponides camposter	Uvigerina spp.	Uvigerina spinulosa	Sigmoilinita tenuis	Chrysalogonium tenuicostatum	Globocassidulina aff. punctata	Obiculoides guazumalensis	Quinqueloculina triangularis	Siphonodosaria frag.
2760	1	1																																												
2770	7	51																																													
2780	7	15																																												
2790	7	14																																													
2800	4	26																																												
2810	51	249	3	1	1																																									
2820	14	105																																												
2830	17	123																																												
2840	43	330		3	2	1	1	1	86	48	16	2	6	1	1																														
2850	24	186							1		1																																		
2860	22	161																																												
2870	23	121																																												
2880	17	65																																												
2890	30	278	3	1	3				7	6		1		1		1	2	1	3	1																									
2900	44	260							17	17	1	1	1								2	1	1	1	1	2																			
2910	23	284		1					13	14	14		2		1		1				6						1	2																	
2920	23	284						1	4	11		3	1				1	3	3		2				4				1	1	1	2	1	1	1									
2930	23	425		1	1				141	63	80	1	24								1						2								1	1	4	3						
2940	24	393							112	78	51	2	5												1		1	4							3		4	2	1	3	1				
2950	19	481		1	1				229	65	71		12					1									10							2		6	3	1						
2960	20	126							48	16	15		8																								1								
2970	10	87							26	16	10		9																																
2980	20	94							26	11	10		6		1										1		1									2								
2990	22	109				2			32	1	13		6																																
3000	11	48							15	5	16		2																														1		
3010	38	448			1				77	17	34		11															1															
3020	33	382							26	6	71		17																																
3030	43	304							6	2	3																																3			1	1
3040	49	253								3		1					1	1				1			1										1										
3050	58	441		13	1				16	6	3	16	1		10		53								3	16	2	3	6					2			7		1		9				
3060	49	310		1					62	24	24		5		3		3	1	1							4				1	6										1				
3070	53	772		6					14	46	2	1	2			1	116	2						5	3		7	1	3		4				9						17				
3080	68	316		3	1	1			6	4	7				5	1	46	1						4	1	2	2				1	1		5						2	1			
3090	53	227							2	2	2	2	2				18	2			2					4	1		1					3						2				
3100	56	270	1						6			1			6		21	3							3	5			2				1	2					2		3			
3110	53	187		1			1		2	6		1	1		6		15	1						2	3	2	1		7					2						1				
3120	62	325				1	2			7		3					73	1				1			3	2	4	3		7					6									
3130	58	293	1	3			1			4	1	1					48	3								7	1	1	1							47			1						
3140	66	400		3	4					9		3					75				2	2		3	1	11	5	4	3						10					3				
3150	51	225			1				4	4	1						31						3		1	2						2			3									
3160	53	247	2	3	4	2			9	5							36	2							1	2	1	1							4			9						
3170	62	268	3	1	1	1			1	4					6		38								1	1	7	1		2					3				2			6	2		1	
3180	50	280	1	1	1				1	5							27			3						6	1		1					1	2									
3190	60	188		1					2	3					4		15					1	1	1		4			2						2						1	1			
3200	54	280				1			2	1	1	4			4		37									3	2								1	1					2				
3210	48	226			3	1				3					3		29									1	1	2	2									1			1	1			
3220	53	283							3						3		9								4	3	2		1	1												1			
3230	60	282								5					6	1	23	2							1		1	1		1		1			1			2			1			
3240	32	150													2		4	1								1	1				1													
3250	31	95																										1							2									
3260	22	86													7											1			1															
3270	21	59													5										1	1																		
3280	23	72													2																													
3290	22	91							3	5					3																													
3300	30	130													4																				1		1							
3310	28	159																								2																		
3320	24	111																																	1									
3330	30	135																							1																			
3340	20	121																																										
3350	25	46		1											1											1																		
3360	13	38																																										
3370	16	83																1																											
3380	11	27																																										
3390	9	17																																										
3410	36	400							52	120	17		6					1			1																								

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Depth (m)	No. species	No. specimens	Ordonella umbonatus	Uvigerina probescidea	Uvigerina mantaensis	Bolivina buchiana	Bolivina multicostata	Bolivina tenuistriata	Neoeponides bradyi	Nodosaria pyrula	Lenticulina aff. mutinodosa	Uvigerina aff. mediterranea	Bulimina spp.	Spiroloculina secreta	Sphaeroidina bulloides	Nodosaria spp.	Cibicidoides grimsdalei	Cibicidoides dohmi	Praeglobobulimina ovata	Amphimorphina aff. stanforthi	Bolivina mexicana	Bolivina spp.	Nodosaria anomala	Sigmoilina elliptica	Gyroidinoides sp.1	Lenticulina formosa	Ammonia aff. parkinsoniana	Ammonia spp.	Ophthalmidium sp.A	Cornuloblimina alazanensis	Fursenkoina bramlettei	Gyroidinoides elegyra	Sorocemena spp.	Nodosaria glandulinoides	Ordonella sp. gr. umbonatus	Cibicidoides sp.1	Ordonella spp.	Glandulina spp.	Ostracod	Gastropod	scaphopod frag.	sponge frag.	fish teeth	planopod	foram lining	fish otolith	diatom infilings
2760	1	1																																					1						
2770	7	51																																					1						
2780	7	15																																												
2790	7	14																																					1	1						
2800	4	28																																						1						
2810	51	249																																						1						
2820	14	105																																												
2830	17	122																																												
2840	43	330																																												
2850	24	186																																												
2860	22	161																																												
2870	23	121																																												
2880	17	65																																												
2890	30	278																																						7						
2900	44	280																																												
2910	23	284																																						4						
2920	23	284																																						3						
2930	23	425																																						3	2						
2940	24	393																																						1						
2950	19	481																																												
2960	20	125																																												
2970	10	87																																												
2980	20	94																																												
2990	22	109																																												
3000	11	48																																												
3010	38	448																																						2						
3020	33	382																																												
3030	43	304																																												
3040	49	253																																						1						
3050	58	441	19	5	10	2	1	2	1	1	1																											7						
3060	49	310	49																																			1		2	3				
3070	53	772	24		30			4	20				2	2	1	3	2																						15						
3080	68	316	16		13											2		1	3	1																		10				2	1		
3090	53	227	12		3			1			1					1			1																			11						
3100	55	270	7		2			5										4	1		2																						1		
3110	53	187	7				1									1	1	1				1	2	1														1						
3120	62	325	6		16	3				3						1		1	1			1		2		1												7						
3130	58	293	15		27	1	3					1	1			4							1				13	1	2														1		
3140	66	400	27		20			13				1				3	5			2	2	4		1			1		1	1									6						
3150	51	225	14		10		5	4								6							1	1								1												
3160	53	247	14		9	1									1	4						1					2						2					1						8
3170	62	268	8		16					1							1		1											1								1						
3180	50	280	13		6		1									3	2												1									2	1					
3190	60	188	9		3		2			1	1											2		1					2			1										1		
3200	54	280	5		2		2										3		1	7			1										1					2						
3210	48	226	11		4											2	2		1	2			2															2						
3220	53	283	3		5												3				1	1												2					3			1			
3230	60	282	10		1		4										1					3																1						
3240	32	150																						1															11						
3250	31	95	1														1	1											1																
3260	22	86			1												2					1																15						
3270	21	59																																	1				7						
3280	23	72	1										3						1																	1			3					1	
3290	22	91	1																																				2						
3300	30	130																					1																6						
3310	28	159																																											
3320	24	111											1																										2						
3330	30	136																					1																6						
3340	20	121																																					1						
3350	25	48																																											
3360	13	38																																											
3370	16	83																																											
3380	11	27																																											
3390	9	17																																					1						
3410	38	400	1					1																												1	2	1			1				

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Depth (m)	Diversity	Abundance	Unidentified fragments	Valvulina flexilis	Glomospira charoides	Cribrostomoides spp.	Reticulophragmium robundidorsatum	Valvulina (early form)	Nothia spp.	Rhabdammina spp.	Ammodiscus latus	Reticulophragmium spp.	Recurvoides spp.	Nothia robusta	Hapkophragmiodes spp.	Trochammina sp. 2	Rhizammina spp.	Saccammina sp. 1	Saccammina spp.	Psammosphaera spp.	Ammomarginulina spp.	Textularia earlandi	Paratrochamminoides spp.	Ammodiscus sp. 1	Hormosina globulifera	Reticulophragmium amplectens	Aschemocella spp.	Ammodiscus spp.	Trochammina spp.	Nothia latissima	Nonion spp.	Cibicidoides spp.	Saccammina cf. spherica
3630	1	3.0	2.0	1.0																													
3640	6	6.0			1.0	1.0	1.0	1.0	1.0	1.0																							
3650	2	3.5	1.0								1.5	1.0																					
3660	3	9.0	2.0				1.0						2.0	4.0																			
3670	3	4.0								1.0	1.0			2.0																			
3680	2	16.0												13.0	1.0																		
3690	4	7.0									3.0	1.0				2.0	3.0																
3700	4	7.0		1.0						1.0				4.0	1.0																		
3710	13	35.0	5.0						1.0	1.0	5.0	1.0	1.0	3.0			5.0	3.0	1.0	3.0	1.0	4.0	1.0										
3720	6	14.0	7.0								1.0			1.0								1.0		2.0	1.0	1.0							
3730	14	49.5	5.0						4.0		4.5						1.0		2.0	2.0		3.0	1.0		2.0		1.0	1.0	3.0	18.0	1.0	1.0	
3740	12	96.5	13.0		1.0						7.0			8.6				2.5				2.5							2.0	48.0			2.0
3750	18	113.0	12.0								2.0			2.0	1.0			9.0				2.0							12.0	58.0			
3760	21	86.0	8.0		3.0				1.0	5.0			1.0	1.0			3.0	1.0	2.0			3.0			1.0			1.5	8.0	31.0			
3770	16	55.0	8.0						5.0	2.0								3.0				1.0			1.0					10.0			
3780	23	135.0	17.0						5.0	11.0	1.0	1.0		6.0			1.0	3.0	5.5			9.0			4.0				1.0	22.0			
3790	24	79.5	1.0		1.0		3.0			4.0	3.5		1.0		0.5		18.0				1.0				3.0			2.0		11.0			2.0
3800	27	171.0	21.0		1.0				3.0	22.0	11.5			5.0			10.0	3.0				2.0			7.0					6.0			
3810	39	153.5	12.0		7.0		3.0		2.0	11.0	6.0	1.0	3.0	2.0	1.0		8.0	1.0	1.0			2.0		1.0	3.0	1.0	1.0			3.0				
3820	45	223.0	16.0		5.0				8.0	3.0	1.0	1.0	3.0	5.0	4.0		39.0	7.0			1.0	4.0		1.0	6.0	5.0				4.0			2.5
3830	42	197.0	8.0		2.0		6.0		3.0	22.0	6.5	2.0		4.0	6.0	2.0	21.0						2.0		5.5	1.0	1.0		3.0	11.0			7.0
3840	40	209.5	10.0		3.0	2.0			1.0	27.0	5.5		4.0	3.0			29.0								5.0	2.0		3.0	13.0	9.0			12.0
3850	30	139.5	25.0							15.0	4.0	3.5		4.0	2.0		16.0				2.0		3.0	2.0	1.0				7.0	3.0			4.0
3860	45	276.5	12.0		3.0	1.0	3.0			25.0	6.5	1.0		14.0	3.0		24.0		2.0			2.0		3.0	7.0	3.0		2.0	4.0	25.0			
3870	40	141.0	9.0		1.0		4.0		1.0	13.0	4.0		1.0	8.0	2.0		36.0				1.0				1.0	3.0				2.0			
3880	33	130.0	5.0		1.0	1.0	3.0			14.0	3.0		4.0		2.0		21.0		0.5									2.0	1.0				
3890	42	189.0	13.0				7.5			29.0	4.0			8.0	4.0		27.0	1.0	1.0			1.0	1.0		2.0	3.0		1.0	2.0	14.0			2.0
3900	36	227.0	23.0		1.0	1.0	2.0			31.0	2.0		2.0	6.0	7.0		53.0					1.0			6.0				3.0	1.0		1.0	2.0
3910	30	129.5	3.0		1.0	1.0				35.0		3.0		9.0	3.0		14.0	1.0							1.5			4.0		5.0			
3920	36	138.5	11.0				6.0		2.0	16.0	7.0		2.0	14.0			16.0						1.0		0.5	2.0		1.0					
3930	29	83.5	13.0		1.0		5.0		8.0	11.0	2.5	2.5	1.0	5.0	1.0		8.0									1.0							1.0
3940	36	147.5	4.0		1.0	3.0	3.0		5.0	23.0	5.5	2.0	5.0	13.0	2.0		17.0						1.0				1.0		3.0				5.0
3950	30	152.0	9.0			3.0	1.0		10.0	21.0	3.0	1.0	5.0	23.0	3.0		29.0	2.0	2.0				2.0			2.0							
3960	31	134.5	13.0		3.0		4.0		2.0	13.0	5.5	2.0	1.0	31.0	3.0		24.0								1.0				1.0				1.0
3970	30	110.5	4.0			1.0	1.0		6.0	12.0	0.5	2.0	1.0	39.0	2.0		10.0		2.5						0.5	1.0					1.0	1.0	
3980	17	106.5	7.0						2.0	9.0	2.0	1.0		49.0	2.0		1.0									2.0		2.0		2.0			4.5
3990	31	148.5	4.0				6.0		5.0	17.0	1.0		1.0	47.0			2.0									3.0		1.0	6.0	9.0			1.0
4000	26	195.0	7.0		1.0		10.0		2.0	8.0	3.0	1.0	2.0	48.0	1.0		2.0		2.0										7.0				
4010	34	231.0	3.0			1.0	3.0		2.0	27.0	2.5	4.0		62.0	1.0		9.0			1.0					3.0				9.0				2.0
4020	23	388.0	4.0			1.0	10.0		2.0	19.0	1.0	2.0	1.0	163.0			3.0											1.0	11.0			1.0	1.0
4030	19	336.0	5.0		1.0		7.0			10.0	1.5	4.0		146.0			5.0		2.0							2.0			6.0				
4040	23	512.0	1.0				8.0			10.0	3.0	2.0		93.0	1.0		2.0	1.0							1.0	3.0			25.0	7.0			3.0
4050	19	221.0	1.0			1.0	6.0			7.0	2.0		2.0	112.0			2.0								4.0	5.0			3.0				2.0
4060	28	371.0	1.0		1.0		11.0		3.0	13.0	2.0	2.0	2.0	110			1.0		2.0							6.0			4.0	3.0			1.0
4070	29	323.0	10.0				7.0		2.0	15.0	6.0	3.0	3.0	157.0	3.0	2.0	4.0						1.0			13.0			6.0	7.0			3.0
4080	24	81.0	3.0				2.0			8.0	3.0	2.0	3.0	15.0	2.0		8.0		1.0							3.0				1.0			1.0
4090	37	309.5	5.0		1.0		9.0		8.0	15.0	2.0	1.0		120.0	3.0		3.0	2.0	1.0				1.0	2.0		5.0							2.0
4100	31	397.5	7.0				17.0		6.0	36.0	5.0	0.5	2.0	161.0			3.0		5.0				1.0			5.0			11.0				1.0
4110	27	257.0	13.0				6.0			26.0	10.0	6.0	2.0	105.0			1.0						1.0			5.0			5.0				
4120	32	315.5	14.0			2.0	11.0		2.0	29.0	9.0	2.0	1.0	141.0						1.0				1.0	3.0	13.0		1.0					4.0
4130	33	201.0	13.0				17.0		6.0	16.0	3.0		2.0	57.0	4.0		2.0		2.0							7.0		1.0					
4140	29	181.0	4.0		2.0		10.0			20.0	6.5	2.0	1.0	46.0	1.0	1.0	6.0	2.0	1.0														
4150	29	235.0	10.0				22.0			15.0	6.0	1.0	3.0	65.0	3.0	1.0	2.0						2.0			3.0		1.0	8.0				1.0
4160	29	127.0	1.0				6.0		1.0	6.0			2.0	19.0			7.0		1.0	1.0						2.0		2.0	4.0				3.0
4170	30	150.0	2.0			1.0	7.0			24.0	3.0	5.0	5.0	26.0	1.0			2.0								2.0			14.0				
4180	26	140.0	3.0			1.0	6.0		1.0	12.0	3.0		2.0	27.0			3.0			1.0								1.0	6.0				
4190	19	103.0	8.0				4.0			11.0	2.0			49.0	1.0														1.0				
4200	14	38.5	1.0				3.0			3.0	0.5			10.0															4.0	1.0			
4210	25	125.0	5.0		2.0		4.0			12.0	1.5	3.0	3.0	36.0	2.0		3.0									2.0							1.0
4220	15	62.0	10.0				5.0			8.0				22.0				1.0	1.0										1.0				
4230	13	76.5	1.0				2.0			20.0		6.0		26.0					1.0										4.0				
4240	21	133.5	2.0				1.0		1.0	16.0				72.0	1.0													1.5	7.0				
4250	16	58.5	2.0				1.0		3.0	1.0				31.0												2.0		1.5					
4260	15	32.0				1.0				6.0	1.0	1.0	1.0	9.0																			
4270	13	52.0	3.0				2.0			4.0				19.0												2.0		2.0	2.0				2.0

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Depth (m)	Diversity	Abundance	Glomospira spp.	Cyclammina spp.	Portatrochammina profunda	Oridorsalis spp.	Ammosphaeroidina spp.	Glomospira irregularis	Reophax sp. 1	Subreophax scalaris	Trochammina sp. 1	Ammosphaeroidina pseudopauciloculata	Trochamminoides spp.	Globigerina (bulloides?)	Pseudononion spp.	Bulimina spp.	Ammolagena clavata	Reophax spp.	Haplophragmoides nauticus	Kamerulina spp.	Recurvoides azuaensis	Nothia aff. excelsa	Haplophragmoides walteri	Ammodiscus sp. 2	Glomospira gordialis	Congophragmium spp.	Verneuilina sp. 1	Kamerlella spp.	Bathysiphon spp.	Bathysiphon sp. 2	Cribrostomoides subglobosus	Ammodiscus cretaceous	Kamerulina conversa
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5	2.0	1.5	6.0	1.0																											
3750	18	113.0	3.0				1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0																	
3760	21	86.0											1.0				2.0	1.0	1.0	2.0	1.5	5.0	3.0										
3770	16	55.0		2.0	1.0																			1.0	1.0	1.0	1.0	2.0	5.0	10.0	1.0		
3780	23	135.0		2.0	20.0		6.0					4.0						1.0	2.0						2.0							1.5	1.0
3790	24	79.5	1.0	0.5	8.0			4.0				4.0							3.0				1.0		1.0								
3800	27	171.0	1.0	0.5	31.0		2.0					1.0						3.0	5.0		1.0	18.0							1.0				
3810	39	153.5	4.0	1.0	21.0					1.0			2.0						5.0		1.0	9.0			2.0				14.0	6.0		1.5	
3820	45	223.0		6.0	20.0					1.0	4.0	6.0	1.0				1.0	3.0	1.0	2.0	1.0	24.0		2.0					2.0	9.0		2.5	
3830	42	197.0			13.0			3.0	2.0			8.0					1.0	2.0			4.0	9.0						2.0		3.0		7.0	4.0
3840	40	209.5	2.0		13.0			1.0		1.0		13.0					2.0		3.0			10.0		1.0	1.0			1.0					
3850	30	139.5			8.0							3.0	1.0								2.0										1.0	
3860	45	276.5	3.0		19.0			6.0		1.0		13.0							9.0		1.0	20.0			2.0			2.0	1.0				
3870	40	141.0			4.0		3.0	2.0	1.0			2.0	1.0					1.0	3.0		2.0										2.0	
3880	33	130.0						4.0		1.0		3.0						3.0	5.0			14.0			2.0					1.0			
3890	42	189.0	4.0		3.0			1.0											1.0		2.0	5.0							1.0	2.0		2.5	
3900	36	227.0	5.0		9.0			1.0				9.0							1.0	2.0		10.0								8.0		5.0	
3910	30	129.5			2.0		7.0	1.0				2.0								3.0		8.0								4.0		2.0	
3920	36	138.5	1.0	2.0	2.0		4.0										1.0				2.0	6.0			1.0					6.0			
3930	29	83.5			1.0			1.0									2.0	3.0		2.0											1.0	1.5	
3940	36	147.5			6.0		1.0					1.0						1.0		2.0	2.0	13.0											
3950	30	152.0		1.0	5.0																2.0	9.0			1.0	3.0							
3960	31	134.5			3.0		2.0			1.0		4.0						1.0	1.0		1.0								2.0				1.0
3970	30	110.5		1.0	1.0		2.0			1.0		4.0						2.0			1.0		2.0						1.0	3.0			
3980	17	106.5		2.0				1.0														7.0				3.0			4.0				
3990	31	148.5			1.0							1.0				1.0			1.0			6.0	3.0						2.0			1.5	
4000	26	195.0	1.0									2.0										15.0	1.0						7.0				
4010	34	231.0	1.0		3.0		2.0					2.0				1.0					2.0	6.0											
4020	23	388.0										2.0								1.0			5.0										
4030	19	336.0																				3.0				1.0							
4040	23	512.0																				5.0								1.0			
4050	19	221.0		3.0							1.0												1.0									1.0	
4060	28	371.0			1.0		6.0				1.0										1.0	3.0	2.0						2.0			1.0	
4070	29	323.0			3.0																2.0		2.0										
4080	24	81.0																	1.0														
4090	37	309.5			2.0		4.0					1.0									1.0	3.0							4.0		2.0	2.0	
4100	31	397.5					5.0					3.0						1.0		2.0		6.0	7.0								1.0		
4110	27	257.0					11.0														1.0	3.0	5.0						3.0		3.0		
4120	32	315.5																				4.0	2.0						8.0		4.0	4.5	
4130	33	201.0					6.0	1.0										3.0		1.0									1.0		1.0	1.0	
4140	29	181.0					10.0					8.0					1.0	4.0			6.0								3.0			1.5	
4150	29	235.0										7.0									3.0	6.0							4.0		4.0		
4160	29	127.0	1.0									3.0							2.0			4.0							2.0			1.0	
4170	30	150.0								2.0		1.0					1.0				2.0	7.0	3.0						4.0		1.0		
4180	26	140.0					1.0															6.0	2.0						6.0			1.0	
4190	19	103.0																											6.0				
4200	14	38.5																			1.0	2.0											
4210	25	125.0														1.0					1.0								5.0				
4220	15	62.0										1.0																	1.0				
4230	13	76.5																														1.5	
4240	21	133.5					3.0															1.0							1.0				
4250	16	58.5														1.0						1.0							1.0		1.0		
4260	15	32.0																			2.0								1.0				
4270	13	52.0										1.0																					

PLUTAO-1 - OLIGOCENE

Depth (m)	Diversity	Abundance	Karreriulina apiculata	Bathysiphon sp. 1	Psammosphaera cf. fusca	Hormosinelloides guttifer	Praesphaerammina sp. 1	Reticulophragmium acutidorsatum	Reticulophragmium gasparensis	Placentammina placenta	Paratrochamminoides olszewskii	Haplophragmoides sp. 1	Reticulophragmium sp. 1	Glomospira sp. 1	Lituotuba lituiformis	Siphonina tenuicarinata?	Reophax pyrifer	Reophax sp. 2	Recurvoides sp.2	Discamminoides sp.1	Trochamminoides subcoronatus	Glomospira glomerata	Praesphaerammina spp.	Trochamminoides aff proteus	Glaphyrammina americana	Pseudonodosinella elongata	Popovia spp.	Reophax pilulifer	Conglophragmium irregularis	Budashevaella spp.	Stilostomella spp.	Paratrochamminoides gorayskii	Paratrochamminoides gorayskiformis
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5																															
3750	18	113.0																															
3760	21	86.0																															
3770	16	55.0																															
3780	23	135.0	1.0	8.0																													
3790	24	79.5			3.0	1.0	1.0	1.0																									
3800	27	171.0			6.0			1.0	4.0	1.0	1.0	2.0	1.0																				
3810	39	153.5						1.0			4.0			1.0	2.0	2.0	2.0	2.0	2.0	1.0													
3820	45	223.0			2.0					1.0				2.0			3.0			3.0	3.0	2.0	1.0	1.0	1.0	2.0	4.0						
3830	42	197.0		4.0	3.0	1.0														3.0	2.0				1.0			2.0	1.0	2.0	1.0	4.0	3.0
3840	40	209.5	2.0	5.0	2.0	3.0		2.0	1.0			1.0	3.0		1.0													2.0					
3850	30	139.5		1.0	13.0		1.0	3.0						2.0						3.0												3.0
3860	45	276.5	2.0	12.0	8.0				2.0						2.0					1.0			1.0				6.0	5.0					
3870	40	141.0	3.0	3.0	2.0			3.0		2.0										1.0		1.0	2.0				1.0			2.0			3.0
3880	33	130.0		8.0	4.0			4.0												3.0			0.5					3.0					
3890	42	189.0		16.0	2.0			3.0			2.0				1.0					4.0			1.0					1.0					
3900	36	227.0		12.0				5.0							2.0					2.0				1.0			1.0		2.0				
3910	30	129.5		5.0	3.0			1.0							2.0					1.0													
3920	36	138.5	3.0	8.0				3.0		1.0	4.0	1.0								4.0			1.0					2.0				1.0	
3930	29	83.5						1.0		1.0			1.0						1.0	2.0													1.0
3940	36	147.5		3.0				7.0											1.0	1.0		1.0	1.0										
3950	30	152.0					2.0	1.0		2.0																	2.0	1.0					3.0
3960	31	134.5		4.0				2.0		2.0	1.0																1.0		1.0				
3970	30	110.5	1.0	7.0				2.0																				1.0					
3980	17	106.5																															
3990	31	148.5						1.0			2.0	1.0	1.0		1.0				2.0	2.0													
4000	26	195.0																		2.0			1.0					1.0					1.0
4010	34	231.0		3.0	1.0			4.5										3.0		2.0								2.0				1.0	
4020	23	388.0						1.0												13.0							2.0	2.0					
4030	19	336.0																	1.0	18.0													
4040	23	512.0		1.0	2.0			3.0			1.0	2.0								27.0													3.0
4050	19	221.0																		3.0													
4060	28	371.0			1.0															6.0								3.0					
4070	29	323.0						2.0		1.0										15.0								5.0					
4080	24	81.0						6.0												2.0								1.0					
4090	37	309.5		3.0				1.0			2.0									15.0								1.5		2.0			
4100	31	397.5			2.0			6.0												19.0								4.0					
4110	27	257.0			4.0			3.0				3.0								8.0													
4120	32	315.5						6.0									1.0			12.0			1.0					2.0				1.0	
4130	33	201.0						3.0							1.0					6.0							4.0	2.0					
4140	29	181.0						6.0							2.0					7.0													
4150	29	235.0						7.0												8.0								4.0					
4160	29	127.0						3.0												2.0	1.0						1.0	3.0					
4170	30	150.0			2.0			7.0			2.0									4.0													
4180	26	140.0			4.0			10.0		1.0										7.0				1.0									
4190	19	103.0						1.0												1.0								1.0					
4200	14	38.5						3.5												1.0								0.5					
4210	25	125.0			2.0			4.0			1.0									1.0								1.5					
4220	15	62.0						4.0											2.0														
4230	13	76.5			1.0			4.0			1.0																							
4240	21	133.5					3.0	4.0												1.0			2.0										
4250	16	58.5					1.0	3.0															2.0										
4260	15	32.0					1.0													1.0													
4270	13	52.0						3.0																				1.0					

PLUTAO-1 - OLIGOCENE

Depth (m)	Diversity	Abundance	Haeuslerella sp. 1	Budashevaella multicamerata	Popovia sp.1	Reophanus berggreni	Glomospira aff irregularis	Cyclammina aff. orbicularis	Glomospira sp. 2	Eggerelloides sp. 1	Subreophax pseudoscalaris	Spiropsammina primula	Ammodiscus aff. peruvianus	Psammosphaera sp. 1	Reticulophragmium amplectens ssp. 1	Scherochorella congonesis	Recurvoides sp. 1	miliolid	Kalamopsis spp.	radiolarian	Rhabdammina linearis	Caudammina aff. ovuloides	Guppyella crassa	Orthomorphina sp.	scaphopod frag.	Hormosina glabra	Evolutinella rotulata	Aschemocella grandis	Alveovalvulina sp. 1	Planulina spp.	Uvigerina spp.	Hormosinella carpenteri	Saccammina sp. 3	Bulbobaculites sp. 1
3630	1	3.0																																
3640	6	6.0																																
3650	2	3.5																																
3660	3	9.0																																
3670	3	4.0																																
3680	2	16.0																																
3690	4	7.0																																
3700	4	7.0																																
3710	13	35.0																																
3720	6	14.0																																
3730	14	49.5																																
3740	12	96.5																																
3750	18	113.0																																
3760	21	86.0																																
3770	16	55.0																																
3780	23	135.0																																
3790	24	79.5																																
3800	27	171.0																																
3810	39	153.5																																
3820	45	223.0																																
3830	42	197.0	1.0																															
3840	40	209.5		2.0	3.0	1.0	4.0	1.0																										
3850	30	139.5			2.0				1.0	1.0	2.0	1.0	1.0																				
3860	45	276.5		5.0								1.0		4.0	2.0	1.0	4.0	1.0	2.0															
3870	40	141.0								1.0									3.0	1.0	1.0	1.0	2.0											
3880	33	130.0		2.0										3.0			1.0		2.0		4.0			1.0	1.0								
3890	42	189.0			1.0												3.0		1.0	3.0					2.0	4.0	1.0	1.0	1.0				
3900	36	227.0	1.0											5.0																2.0	1.0	1.0		
3910	30	129.5									2.0				1.0													1.0				7.0	1.0
3920	36	138.5			2.0				1.0												1.0											1.0	
3930	29	83.5															1.0																
3940	36	147.5			1.0		1.0								1.0	1.0			7.0													1.0	
3950	30	152.0		2.0												1.0			1.0													2.0	
3960	31	134.5																										1.0					
3970	30	110.5											1.0																				
3980	17	106.5														6.0																	
3990	31	148.5														14.0			1.0					2.0									
4000	26	195.0			1.0											65.0																1.0	
4010	34	231.0	1.0													62.0								1.0									
4020	23	388.0												2.0		378.0																	
4030	19	336.0							1.0							120.0			1.0													0.5	
4040	23	512.0														307.0																	
4050	19	221.0														63.0											1.0						
4060	28	371.0														57.0																	
4070	29	323.0										1.0		1.0		45.0											1.0						
4080	24	81.0											1.0			7.0			1.0														
4090	37	309.5		2.0												65.0																	
4100	31	397.5												1.0	1.0	72.0																	
4110	27	257.0			2.0									1.0		20.0																	
4120	32	315.5														28.0											2.0						
4130	33	201.0														18.0											7.0		1.0				
4140	29	181.0												1.0	2.0	11.0																	
4150	29	235.0												1.0		25.0						1.0									2.0		
4160	29	127.0														17.0															1.0		
4170	30	150.0										1.0			1.0	9.0																	
4180	26	140.0														20.0																	
4190	19	103.0						1.0						1.0		7.0											1.0						
4200	14	38.5														5.0																	
4210	25	125.0														6.0																	
4220	15	62.0																													1.0		
4230	13	76.5														5.0											1.0						
4240	21	133.5														9.0																	
4250	16	58.5														4.0																	
4260	15	32.0					1.0								1.0	2.0																	
4270	13	52.0														5.0																	

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Depth (m)	Diversity	Abundance	Hyperammina spp.	Cyclammina sp. 1	Haplophragmoides carinatus	Cyclammina sp. 2	Paratrochamminoides sp. 1	Saccammina sp. 2	Glaphyrammina spp.	Trochamminoides folius	Haplophragmoides aff. horridus	Haplophragmoides sp.2	Reophax duplex	Hormosina sp.	Jaculella sp. 1	Hyperammina elongata	Paratrochamminoides aff. deflexiformis	Recurvoides sp. 3	Rhabdammina sp. 1	Paratrochamminoides ex gr. challengeri	Cassidulina spp.	Valvulineria spp.	R. amplectens / scutidorsatum trans.	Reticulophragmium intermedium	Karrerulina horrida	Reticulophragmium acutidorsatum. ssp.	Ammodiscus tenuissimus	Gyroidina spp.	Subbotina eocena (plank)	Buzasina aff. pacifica	Bolivina spp.	Chrysalogonium spp.	Psammosphaera 2
3630	1	3.0																															
3640	6	6.0																															
3650	2	3.5																															
3660	3	9.0																															
3670	3	4.0																															
3680	2	16.0																															
3690	4	7.0																															
3700	4	7.0																															
3710	13	35.0																															
3720	6	14.0																															
3730	14	49.5																															
3740	12	96.5																															
3750	18	113.0																															
3760	21	86.0																															
3770	16	55.0																															
3780	23	135.0																															
3790	24	79.5																															
3800	27	171.0																															
3810	39	153.5																															
3820	45	223.0																															
3830	42	197.0																															
3840	40	209.5																															
3850	30	139.5																															
3860	45	276.5																															
3870	40	141.0																															
3880	33	130.0																															
3890	42	189.0																															
3900	36	227.0																															
3910	30	129.5	1.0																														
3920	36	138.5		1.0	1.0																												
3930	29	83.5	1.0			1.0	2.0																										
3940	36	147.5						1.0	1.0																								
3950	30	152.0																															
3960	31	134.5								1.0	1.0																						
3970	30	110.5																															
3980	17	106.5																															
3990	31	148.5						1.0																									
4000	26	195.0										1.0	2.0																				
4010	34	231.0	1.0											1.0	1.0	1.0																	
4020	23	388.0									1.0																						
4030	19	336.0															1.0																
4040	23	512.0																															
4050	19	221.0		1.0														1.0															
4060	28	371.0																	1.0	1.0													
4070	29	323.0	1.0										1.0					3.0															
4080	24	81.0	1.0															1.0			1.0	6.0	1.0										
4090	37	309.5			2.0													7.0		1.0			1.0	6.0	2.0								
4100	31	397.5											1.0		1.0									4.0		1.0							
4110	27	257.0									3.0							3.0						1.0			1.0						
4120	32	315.5				1.0							1.0											2.0				1.0	1.0				
4130	33	201.0	1.0		1.0						1.0							8.0				2.0				1.0				1.0			
4140	29	181.0																4.0			1.0	8.0									1.0		
4150	29	235.0									3.0											16.0									1.0		
4160	29	127.0																1.0			1.0	25.0									4.0		
4170	30	150.0	1.0															7.0	2.0			1.0											
4180	26	140.0																			2.0	10.0	2.0									1.0	
4190	19	103.0	1.0															2.0				5.0	1.0										1.0
4200	14	38.5																			2.0	1.0											
4210	25	125.0																3.0			6.0	19.0	1.0									1.0	
4220	15	62.0																1.0			1.0	2.0	1.0										
4230	13	76.5																					1.0										
4240	21	133.5									1.0						1.0				2.0	2.0	1.0	1.0									
4250	16	58.5	1.0																		2.0												
4260	15	32.0																3.0				1.0											
4270	13	52.0																3.0				3.0											

SATURNO-1

| Depth (m) | No. species | No. specimens | Undil stained | Undil calc | Undil plank | Trochammina spp. | Rhabdammina spp. | Hyperammina spp. | Hyperammina spp. | Hyper

SATURNO-1

Depth (m)	No. species	No. specimens	Trochammina sp. 1	Trochammina sp. 2	Valvulina fusiformis	Eggerella bradyi	Ammonia spp.	Cribrostomoides sp. 1 (fragile)	Praesphaerammina spp.	Karreriella apicularis	Glomospira sp. 1	Haplophragmoides rotulus	Subreophax scalaris	Ammolagena clavata	Haplophragmoides sp. 1	Cyclammina (frag)	Reophax pilulifer	Pseudonodosinella nodulosa	Tolypammina spp.	Cyclammina spp.	Psammosphaera sp. 2	Reticulophragmium spp.	Reticulophragmium rotundidorsatum	Budashevaella multicamerata	Glomospira sp. 2	Paratrochamminoides sp. 1	Ammodiscus aff. peruvianus	Recurvoides sp. 1	Hyperammina elongata	Psammosphonella cylindrica	Ammodiscus glabratus	Paratrochamminoides spp.	Gaudryina atlantica	Kalamopsis spp.	Portatrochammina profunda	Liuvotuba filiformis	Textularia earlandi	Trochamminoides challengeri	Reticulophragmium sp. 1	Discamminoides sp. 1	Cibicidoides spp.	Reticulophragmium galapagensis	Trochamminoides subcoronatus	Reophanus berggreni	sea/hopod frag.	Brizalina cf. barbata	Nonion sp. 2	Paratrochamminoides aff. deflexiformis
2875	19	98																																											
2885	24	149																																												
2895	7	13																																											
2900	7	12																																											
2910	19	119	1	1	1	2																																							
2920	16	131	9				1	1	1																																			
2930	21	90	3					1		1	1	2																																	
2940	23	143	3					2	1	2			1	1	1																													
2950	27	167	1	1				1	1							5	1	1	4	1	1																							
2960	31	138	2						2	2	1											3	1	1	1	1																		
2970	22	199	2					1	1			1	2									1					1	1																
2980	31	153	2		1			1	1		1		3			1			2									2	1																
2990	37	173	3		1					1	1		1		2	1	1				1		1		2				9	1	1												
3000	33	179	6					1	2	1					1	1									1		1			1		1	1	1									
3010	36	171	1					3	2	2	2				1		3									3				1		1	1		2	1	1						
3020	27	180	1					1	1	1	3		2	2	2									2			2			3													
3030	36	207	6		1			3		4		1		1	2	2	1						1		1					13		1			1			2	1	1		
3040	31	230	2		1				1			1					1		1			2						2		9		3						1	1				
3050	28	173	6	1					1		1					2	1					1		1		1				15		1										
3060	28	170	3					1	2			1		1								1		1			1			14	1											
3070	23	147	3		1					2		1	1														1			9	1	1			1							
3080	23	200	5		2			1			1	4				2				2										4	1	1										
3090	40	239	8							6	1		2		2	1	2		1	1		1	1	1			1			2		1			1				1			
3100	20	97	1					1		1	1				6					1			1					1		1											
3110	14	62	1								1				2														6												
3120	10	30										1																	1												
3130	13	38																					1																		
3140	13	38													1								1																		
3150	6	8																																							
3160	6	13																									1														
3170	15	88	1										1			1																										
3180	12	70											2																													
3190	11	60																																								
3200	12	41	1																				1																4			
3210	16	63	1														1						1		3	1																
3220	16	88	1					1																						1									1			
3230	13	48														1							1							2											
3240	11	33	1																1	1		3																			
3250	17	46	2							1	2					3						1	1							1											
3260	15	29	1																																					1			
3270	11	26													2								1						1		1										2	
3280	8	14	1																				1																			
3290	11	21																	1			1																		1	1	
3300	33	116										1	1				2		1	1								1								2		1					
3310	5	7																	1																							
3320	3	8	1																			1		1																		
3330	3	3																																								
3340	2	5																																								
3350	3	5																																						1		
3360	4	8																																								
3370	3	9																																								
3380	3	5																												1												
3390	5	8						1							1																	1										
3400	18	84	1																			3														1						
3410	16	86						1			1																																
3420	17	72	2																				1							6												
3430	20	95						1					2									2										1	1									
3440	16	49																					1									1										
3450	5	14																				1																				
3460	8	16	2																			1																				
3470	3	4	1																																							
3480	3	3																																								
3490	9	110																										1														
3500	17	103	1						1																			1				1										
3510	9	110														1							1					1														
3520	9	93																										1				1										
3530	15	111														3							1							1												
3540	7	23																																									
3550	23	94	1													1												3				1										
3560	32	102									2					2			1			1	1								1											
3570	26	77													1	1						1		1							2		1			1						

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Depth (m)	No. species	No. specimens	Nonion sp. 1	Ammodiscus tenuissimus	Buzasina pacifica	Haplophragmoides sp. 2	Haplophragmoides wallen	Bulimina elongata	Haplophragmoides horridus	Oridorsalis umbonatus	Reophax spp.	Spiropsammina primula	Glomospira glomerata	Reophax duplex	Cauldammina ovuloides	Reticulophragmium intermedium	Ammomarginulina spp	Paratrochamminoides gorayskiformis	Paratrochamminoides olszewskii	Glomospira aff. serpens	Reophax sp. 2	Conglophragmium irregulare	Verneuilina sp. 1	Subreophax pseudoscalaris	Reophax pyriformis	Paratrochamminoides gorayski	Rhabdammina linearis	Normosnellodes glabra	Karrerulina conformis	Karrerulina conversa	Nodosaria spp	Trochamminoides spp	Scherochorella congoensis	Reticulophragmium sp. 2 (excavatum)	Ammodiscus cretaceus	Hyperammina spp.	Reticulophragmium venezuelanum	Normolina glabra	Ammodiscus sp. 1	Subreophax spp.	Bolivina spp.	Uvigerina spp.	Nonion spp.	ostracod	Pseudonodosinella elongata	Praeglobobulimina spp.	miliolid inner
2875	19	88																																											
2886	24	149																																												
2895	7	13																																											
2900	7	13																																											
2910	18	119																																											
2920	18	131																																											
2930	21	90																																											
2940	23	143																																											
2950	27	167																																											
2960	31	139																																											
2970	22	186																																											
2980	31	163																																											
2990	27	173																																											
3000	33	176																																											
3010	34	171																																											
3020	27	189																																											
3030	36	267																																											
3040	31	239																																											
3050	28	179																																											
3060	28	178																																											
3070	23	147																																											
3080	33	259																																											
3090	40	236																																											
3100	23	97																																											
3110	14	62																																											
3120	10	39																																											
3130	13	39																																											
3140	13	36																																											
3150	6	8																																											
3160	5	13																																											
3170	15	66																																											
3180	12	76																																											
3190	11	40																																											
3200	12	41																																											
3210	16	63																																											
3220	16	66																																											
3230	13	46																																											
3240	11	33																																											
3250	17	46																																											
3260	15	29																																											
3270	11	28																																											
3280	8	14																																											
3290	11	21	1																																											
3300	33	116		1	1	1	1																																							
3310	5	7						1																																						
3320	3	6						1																																						
3330	3	3																																											
3340	2	5																																											
3350	3	5																																											
3360	4	8																																											
3370	3	9																																											
3380	3	5																																											
3390	5	8																																											
3400	18	84																																											
3410	16	85							2																																				
3420	17	72							1	1																																			
3430	20	85							1																																				
3440	16	49						1																																					
3450	5	14																																											
3460	9	18									1																																		
3470	3	4																																											
3480	3	3																																											
3490	8	118																																											
3500	17	103																																											
3510	9	118				1																																						
3520	9	53																																											
3530	15	111				2																																						
3540	7	23											1																																
3550	23	94				1							1	1	1																														
3560	32	102		2							1		1		1	2	1																												
3570	26	77															1																												

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Depth (m)	No. species	No. specimens	Undif agglut	Undif calc	Undif plank	Trochammina spp.	Rhabdammina spp.	Haplophragmoides spp.	Megastomella afrocena	Volutinaria pseudolumpyensis	Saccammina spp.	Ammodiscus spp.	Karrerulina spp.	Cribrostomoides subglobosus	Textularia spp.	Cassidulinella plioceanica	Praeglobobulimina socialis	Globigerina bulloides	Uvigerina canariensis	Cibicidoides mundulus	Dorothia brevis	Aschemocella grandis	Bathysiphon spp.	Rhizammina spp.	Haplophragmoides kirsty	Glomospira irregularis	Glomospira gordialis	Glomospira charoides	Glomospira aff. serpens	Eggerelloides sp. 1	Reticulophragmium acutidorsatum	Ammosphaeroidina pseudopauciloculata	Recurvoides azuaensis	Recurvoides spp.	Nonionella globulifera	Ammodiscus latus	Haplophragmoides canariensis	Brizalina rifata	Reticulophragmium amplectens	Psammosphaera spp.	Glomospira spp.	Glaphyrammina americana	Glandulina ovula	Ioanella spp.	Ammodiscus spp.	Chrysalogonium spp.	Reticulophragmium orbiculatis	Placentammina placenta
3580	23	98	11			7	10				3	18										4	2				1			1	2			2	1	1					15	5			
3590	31	119	23			4	17	1			2	4									1	5	3	2		1	3			1	2	2	1		7				1		8	1			
3600	32	134	23			8	18	1			2	8	1									6	3	1		2	3					1	10						2	1	15				
3610	19	39	9			2	3	1			1	1										2	4				2						1								7				1
3620	14	89	10			7	12															4	4				1			2								2	1	6	1			
3630	29	91	22			5	14				3		1									6	3	1		1	1			2	1			2		1	2	1			3				
3640	15	60	24			1	11				3											4	1				1				2		1								6	1			
3650	22	78	16			4	7	1			5	6		2								6	5	3			2						1		1					1		4	2			1
3660	29	108	21			8	14	3			6	4		2									4	1	1		4				1	2		1	1					2			10	2		
3670	16	62	12			3	8				2	7											2				1							4	1					2			8			
3680	17	41	11			1	8	2				2									1	3	1				1			1										1	1					
3690	13	31	13			3	2				1		1									1					1								1						1		2			
3700	32	166	46			15	28	1			7	7		1								11	9	1			1				4		1	2	4						4			8			1
3710	25	186	17		2	16	17				5	6	1	1								5	4				1			3		1	2	7						3	1		11	6		
3720	18	126	21			36	17	1			4	11									1	2	7							2	1			2						1			6	2		
3730	19	187	14			42	21				2	6										6	7									3	2	6						4	1		7	1		
3740	16	136	15			28	20				2	21										2	2				1			2				8									9	1		
3750	29	389	34			46	23	1			3	33	1									6	6				2			4	4		2	2	6						1			10	2		
3760	16	331	9			36	15				1	7										7	5							2	2		1	6					1			5	2		
3770	28	241	7			34	26	1			1	28									2	6		1	1					2				7						4			12	1		
3780	28	344	16			54	21				3	24	1									10	1	1	1	1	1			3	2			2	1								13	4		
3790	28	182	10			21	36				7	13	1									7	11				2			3			1	4					1			13	5		
3800	25	104	15			9	14				4	6	1									6	11				1				2		3	6						1			9	3		
3810	19	79	9		1	23	15	1			3	2										2	2				1			3			1	1	6								1	2		
3820	14	78	8			23	18	1			3	2										2											1	1									0	3		
3830	9	157	2			107	2				1	7										3								2				9											
3840	11	319	2			181	4				1	64									1	1												2								2			
3850	10	262	7			91	3	1			1	89										1											1	2								3			
3860	8	296	2			131	2				1	119										1								1												1			
3870	9	209	1			116	3				1	89									1	3																				1			
3880	12	209	2			87	2					79									1	3	1							1	1			2								3	2		
3890	11	288	2			113	1				1	109										1								1			1									1	1		
3900	9	114	1			85	3					13	1										1																				1	1		
3910	6	149	0			88	1					29									1	1																	1						
3920	15	230	2			122					1	87										1	3								2	1	1								1			6			
3930	8	300	0			78	3				1	74										3												8											
3940	12	284	3			107	2					46										1	1									1		6								1	3		
3950	14	246	8			73	1				2	37										1	3							1				6								2	2	2	
3960	9	143	4			46					1	30										2																					1	2		
3970	11	184	8			48	2				2	22										1	2											6									1	0		
3980	13	102	6			34	3				1	12										3	4									2	2	3								2	5		
3990	19	191	8			40	21				2	21	1										10											2			1						12		
4000	16	266	5			144	24				6	25										6	3							1				3									16	2		
4010	16	128	11			58	12				4	19										3	4								1	1		3									5			
4020	21	309	14	2		203	18	1			2	15											7							1	1	1	2	1								2				
4030	22	344	10			209	33	1			4	11	3									1	2										1	3								1	7	1		
4040	24	180	17			73	12	1			1	8							1			3	2	1						4	2		6	1								2	2	2		
4050	17	274	7			194	16	1			6	16										4	3										2									6	1	11	1		
4060	21	345	3		1	288	22	3			2	13										1	8							1	1		1	2									1	1		
4070	25	406	21			313	18				3	6	1									7	6	1						2	2			9	2							2		2	4		
4080	17	363	8			313	8				3		1									3	2							2	1		1		1								6	2		
4090	20	364	13			301	6	2			5	2	3									2	3	1						2		2	1	3								2	3	2		
4100	15	175	8		1	139	2				1	4																		1	2												1			
4110	15	187	8			167	7	1			3	3										1											1									4	2		
4120	15	158	4		1	123	9				2	3	1										1										1											2		
4130	19	301	8			227	18					16										3	8		1					1			1	1								4		1	2		
4140	17	226	11	1	1	143	13				3	24										2	2			2																1		12	1	1	
4150	13	128	2			84	2					18										2	2							1		1										1	7	1		
4160	19	163	7			98	9	1			2	15										3	3							1	1	1	1									1	3		1	
4170	14	156	4		1	103	0				2	18										1	2									1										1	3	1		
4180	18	145	1		2	81	8	1			1	25											1												1							2		3		1	1
4190	16	154	6			86	6	2			1	21	1										1																				2		7		1	
4200	16	277	4		1	214	5				1	6										1												1									2		3			
4210	15	261	2		1	276	5				2	23										1	3							1		2	1										4	1	1	
4220	12	349	3		2	291	6					10										1																					1	1	2	1	
4230	10	310	1			298	8				1	9										2																					1	4			
4240	8	192	1			181						11										1																					1	1			
4250	12	194	3			149	4					13										1											1									2		1		
4260	9	229	1			183	3				1	15	1																														1				
4270	8	79	4			54					1	9										1																					1				
4280	6	106	2	1		82	1					4											1																								

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Depth (m)	No. species	No. specimens	Trochammina sp. 1	Trochammina sp. 2	Valvulina fusiformis	Eggerella bradyi	Ammonia spp.	Cribrostomoides sp. 1 (fragil)	Praesphaeramminia spp.	Karrusella spiculans	Glomospira sp. 1	Haplophragmoides rotulicus	Subreophax scalaris	Ammolagena clavata	Haplophragmoides sp. 1	Cyclammina (frag)	Reophax pilulifer	Pseudonodosinella nodulosa	Tolypammina spp.	Cyclammina spp.	Psammosphaera sp. 2	Reticulophragmium spp.	Reticulophragmium rotundidorsatum	Butschliweyella multicamerata	Glomospira sp. 2	Paratrochamminoides sp. 1	Ammodiscus sif. planiformis	Recurvoides sp. 1	Hyperammina elongata	Psammosiphonella cylindrica	Ammodiscus gullbrandi	Paratrochamminoides spp.	Gaudryina atlantica	Kalamopsis spp.	Portatrochammina profunda	Lituotuba lituiformis	Textularia earlandi	Trochamminoides challengeri	Reticulophragmium sp. 1	Discamminoides sp. 1	Obiculoides spp.	Reticulophragmium gasparensis	Trochamminoides subcoronatus	Reophanus berggreni	ecaphopod frag.	Brizalina cf. barbata	Nonion sp. 2	Paratrochamminoides aff. deflexiformis
3580	23	94											1				1					2						2																		
3590	31	115	1					1									7					1	1					2		6		1						2								
3600	32	134								1							3					3	2	1				7				2			2			1			1				
3610	15	39																										2					1												
3620	14	58																					2					3						1											
3630	26	91	1																			1						2						1				1							
3640	15	60	1																			1											1											
3650	22	75	1														3														3													
3660	29	102															6										1	1		1		1												
3670	16	62	1														1											1		4														
3680	17	41															2						1																				
3690	13	31	1														2																										
3700	32	186	1								1			1	1		1						1					4		1		1			1								
3710	25	186		1													1														2			6				1					
3720	19	129															1																	7									
3730	19	167										1										1							1					19									
3740	16	136	1																															20				2					
3750	28	338										2	1									2	2				1							31	1			1					
3760	18	331											1				2																	29				3					
3770	25	241	1														2						1					1							17				2					
3780	28	344										3																						32	1			7					
3790	28	192	2							1		2					2					1					1					1		4	1			3			1		
3800	23	104															2							2				1		2					1				1				
3810	16	79										2											2											6									
3820	14	78																														1		4				4					
3830	9	157																																24									
3840	11	310										1					1																	46									
3850	10	242																																43									
3860	6	296																																44									
3870	9	209																																21									
3880	12	208																																29									
3890	11	268													1																			38									
3900	6	114															1																	27									
3910	8	148										1																						27									
3920	15	230			1												1											2						18									
3930	6	200																																31									
3940	12	264																												1				123									
3950	14	240															1															1		108									
3960	9	143																				1												51									
3970	11	155																				1												56									
3980	13	102										1										1												24									
3990	19	151	1									2										1	3											26									
4000	15	256							3			1										3	6											13									
4010	16	128										1											2											3	1								
4020	21	300	2																			1	4					1						5				4					
4030	22	345	1																				2					1						18									
4040	24	160	1																			1	1									1		1				3					
4050	17	274																				1	2					1							1				1					
4060	21	348	1										2									3	3	1										2				8					
4070	29	409	1		1							2											3					1				1		3				1					
4080	17	363																					1	1										6									
4090	20	388											1																					1	1								
4100	15	175	3														2					2	4											8									
4110	15	187											1										2					1						6	1								
4120	15	158											1				2					1	2											2	1			2					
4130	19	301															1						2										1	1				1					
4140	17	228				1																	2					1						2				2					
4150	13	126																				2	2					1															
4160	18	165																				2	1	1										4									
4170	14	158																				1	2											11				1					
4180	18	145	1																			1	4											6									
4190	16	184	2										1										1											6									
4200	16	277	2																			11	11						1					6				1	3				
4210	15	361																					9											28				3					
4220	12	346															1						9											19				1					
4230	10	310																					2											25				1					
4240	8	192															1						3											22									
4250	12	194											1									3	3											11				2					
4260	9	228																					2											21				1					
4270	6	79																				1	2											6									
4280	8	104																																12					1				

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Depth (m)	No. species	No. specimens	Nonion sp. 1	Ammodiscus tenuissimus	Buzasina pacifica	Haplophragmoides sp. 2	Haplophragmoides wallen	Bulimina elongata	Haplophragmoides horridus	Oridorsalis umbonatus	Reophax spp.	Spiroplectammina primula	Glomospira glomerata	Reophax duplex	Caudammina ovuloides	Reticulophragmium intermedium	Ammomarginulina spp.	Paratrochamminoides gorayskiformis	Paratrochamminoides olszewskii	Glomospira aff. serpens	Reophax sp. 2	Conglophragmium irregulare	Verneuilina sp. 1	Subreophax pseudoscalaris	Reophax pyrifer	Paratrochamminoides gorayski	Rhabdammina linearis	Normalinoides gullfer	Kamerulina conformis	Kamerulina cenverga	Nodosaria spp.	Trochamminoides spp.	Scherochorella congoensis	Reticulophragmium sp. 2 (secrevatum)	Ammodiscus cretaceus	Hyperammina spp.	Reticulophragmium venezuelanum	Hormosina globra	Ammodiscus sp. 1	Subreophax spp.	Bolivina spp.	Uvigerina spp.	Nonion spp.	ostracod	Pseudonodosinella elongata	Praeglobobulimina spp.	triloculd inner
3580	23	94					1																																						
3590	31	119															1	2	1																											
3600	32	134		1								2						2	3	1	1																								
3610	16	39																				1	1																						
3620	14	56		1																																								
3630	29	91					3					1					1		3					1	1	2																	
3640	16	66									1					1																												
3660	22	78					1		1							1																												
3680	29	102												1			1					1						1	1	1														
3670	18	62												1			1													2														
3680	17	41										1									1							1		1														
3690	13	31																	1													1												
3700	32	166				1					1	1										1								2														
3710	28	166					1												1														1										
3720	19	129												1	2													1																
3730	19	157														1																	4										
3740	16	136																															1	1									
3750	28	309									1															1							84										
3760	18	331																															194										
3770	25	341				1	1										1													1		80										
3780	25	344												1								1											137										
3790	28	162					2							1																1			9										
3800	23	104							1			1			1																													
3810	18	79																				1																						
3820	14	78																																	1									
3830	9	157																																		1								
3840	11	315																																										
3850	10	342																																									
3860	8	299																																									
3870	9	309																																		1								
3880	12	309																																										
3890	11	388																																									
3900	9	114																																									
3910	8	149																																									
3920	10	230																		1																								
3930	8	309																	1																								
3940	12	294																																			1							
3950	14	249																																										
3960	9	143																																			3							
3970	11	155																																										
3980	13	102																																									
3990	10	151									1																																
4000	15	259																																									
4010	16	126																																									
4020	21	300										1																																
4030	22	346					1				3																																
4040	24	150									1																																
4050	17	274																																									
4060	21	345																																									
4070	23	408																																									
4080	17	365									1																																
4090	20	358																																									
4100	15	179															1										1																
4110	19	187																																									
4120	15	156																																									
4130	19	301									2																1																
4140	17	226									1																																
4150	13	126																																									
4160	18	153																																									
4170	14	156																																									
4180	18	145																									1																
4190	18	154									1																																
4200	16	277									1																																
4210	15	361																																									
4220	12	348																																									
4230	10	310																																									
4240	8	192																																									
4250	12	194																																									
4260	9	229																																									
4270	8	79																																									
4280	9	104																																									

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Depth (m)	No. species	No. specimens	Undif agglut	Undif calc	Undif plank	Trochammina spp.	Rhabdammina spp.	Haplophragmoides spp.	Magasetomella africana	Valvulineria pseudobeyrichi	Saccammina spp.	Nothia robusta	Kamurolina spp.	Cribrostomoides subglobosus	Tsudaiera spp.	Cassidulinella pliocenica	Praeglobobulimina soceki	Globigerina bulloides	Uvigerina canariana	Obcaldoia mundulus	Dorothia brevis	Aschemocella grandis	Bathysiphon spp.	Rhizammina spp.	Haplophragmoides bradyi	Glomospira irregularis	Glomospira gordialis	Glomospira charoides	Glomospira aff. serpens	Eggerellodes sp. 1	Reticulophragmum acutidorsatum	Ammosphaeroidina pseudopauciloculata	Recurvoides sauvagesi	Recurvoides spp.	Hormosina globulifera	Ammodiscus latus	Haplophragmoides canariensis	Birsteina orbicularis	Reticulophragmum amplectens	Psammosphaera spp.	Glomospira spp.	Saphyrammina americana	Glandulina ovula	Nothia spp.	Ammodiscus spp.	Chrysalidogonium spp.	Reticulophragmum orbiculare	Placentammina placenta
4280	12	78	1	1		48	3				1	6												1									1													
4300	7	62	1			55	4					14																					2			1										
4310	6	46	4			36					1	9																																		
4320	6	41	3			29					1	7												1																						
4330	6	31	1			21					1	1																																		
4340	6	46	3		1	16	1				2	13																																	
4360	5	39	1			13						4																																	
4380	6	23	0			17	3					1																				1												
4370	9	39	3			18	1				1																				1	1							1				
4380	4	11	2			4	1					1																														3			
4390	7	34	0		1	18	2					3												1																	2			
4400	9	141	0		1	86	27				2	10																														31			
4410	8	136	2			9	68					13	1											6																		37			
4420	7	77	1			2	21					28												1									1									26			
4430	9	106	9			18	31				1	17	2											1																		28			
4440	10	91	2			3	24				1	9												3	1																	36			
4450	7	34	2			2	9					10																														7	1		
4460	9	88	0			11	11					19												2																1		13			
4470	8	38	0			5	6					8	1																										1			11		1	
4480	5	11	0			3	4					1												2																		1			
4490	3	8	2			1	4																																		1			
4500	4	16	4			7	1					3																														1			
4510	4	10	2			4	1				1																															2			
4520	5	24	2	2		13						3												2									1												
4530	10	30	5	1		7	1				1	3																				1									3			
4540	8	27	4	3		3	4					5												4											1									
4550	7	24	0			11	3				1	7												2																		4			
4560	7	49	3			18	11					6																				1		1							6			
4570	11	54	6			19	9				2	9											1					1										1			2	1		
4580	9	72	9			37	6				2	7											1	2								1									6			
4590	17	115	6			53	10					7											1				2			1	2		1						1		7			1
4600	24	184	7			100	19	1			3	5	2										3	12		1					1	1							1	1	9	1		
4610	22	173	22			36	33	2			6	12											2	24				4			1	3		5		1			1	2	1	4	1		
4620	16	88	14			17	41	1				2												9			1				3	2							1	1	3	3		
4630	17	108	6			22	29				1	24												10				2				1		2						1		3	1		
4640	13	122	5			46	12				4	33	1										2	9							1									1	2			
4650	6	130	5		1	72					4	41																																1
4660	14	145	3			85	7	1			1	46												3									1								2			
4670	13	74	2			16	2				1	56												7							1	1	1											
4680	12	80	3		1	17	7	1			1	36											1	8											1						2			
4690	11	71	1			32	4				2	20	2											5															1		1			
4700	11	80	0	2		36	4				2	27														1						1			1						2			
4710	14	88	2	1		11	5	1			1	33												4																	3			
4720	14	88	4			13	4	2			2	17											1	6								1	1								1			
4730	12	47	8	1		14	6				1	11	1										1	1								1	1											
4740	12	48	4		1	8	12				1	11												2									1								2			
4750	12	62	3			18	7	2				17											1	7							1		2											
4760	19	105	13			28	10	1			2	34											3	3															1	1	3	1		
4770	12	112	20			17	15	2			2	40												3								1		2							3			
4780	13	112	58			10	13				1	15																					1	1				1	2		6	1		
4790	16	147	45			16	28				3	36												7										3						1		1		
4800	14	139	43	2		17	11	1				39		1										5							1	2		2					1			6	3		
4810	13	202	2		1	32	1	2			1	156	1	1										4										1		1						1	2		
4820	8	174	2			28	1					132												1											5				3					
4830	11	188	3			20	1				1	148												5																	2			
4840	9	227	7			33						172	1											4															3						
4850	9	114	9	1		17	2				3	78												3											1									
4860	10	96	1			4					2	79												1									2						1		2			
4870	11	80	1			4	2				1	40											1	2									1							1		5			
4880	9	121	8			5	1				3	97												1									2						1		1			
4890	8	110	5			9					1	94												3				1											1		1			
4900	6	124	1		1	5					1	107												2																	6			
4910	10	102	5			6					2	138										1		2																	2	1		
4920	3	79	0			4	1				1	72																1															
4930	5	154	2			2					2	146																												1		1			
4940	5	62	0			1	2					57												1															1					
4950	2	11	1									9																													1					
4960	3	30	0			1						28																																		
4970	4	16	0			3						11																		1									1						
4980	5	10	0			3						4												1						1			1											
4990	2	4	0									3																																		
5000	5	21	4	3		2	1	1				8																					2											

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Depth (m)	No. species	No. specimens	Trochammina sp. 1	Trochammina sp. 2	Valvulina fusiis	Siggenila bradyi	Ammonia spp.	Cribrostomoides sp. 1 (huge)	Praesphaerammina spp.	Komokiina apiculata	Glomospira sp. 1	Haplophragmoides rostratus	Subreophax scalaris	Ammolagena clavata	Haplophragmoides sp. 1	Cyclammina (frag)	Reophax pilulifer	Pseudonodosinella nodulosa	Tolypammina spp.	Cyclammina spp.	Psammosphaera sp. 2	Reticulophragmium spp.	Reticulophragmium rotundidorsatum	Budashevella multicamerata	Glomospira sp. 2	Paratrochamminoides sp. 1	Ammodiscus aff. paviarius	Recurvoides sp. 1	Hyperammina elongata	Psammosiphonella cylindrica	Ammodiscus gullbrulis	Paratrochamminoides spp.	Gaudryina atlantica	Kalamopsis spp.	Portatrochammina profunda	Lituotuba lituiformis	Tritaxilina cariandi	Trochamminoides challengeri	Reticulophragmium sp. 1	Discamminoides sp. 1	Obsidioides spp.	Reticulophragmium glasgowensis	Trochamminoides subcoronatus	Recophanus berggreni	scaphopod frag.	Brizalina cf. barbata	Nonion sp. 2	Paratrochamminoides aff. deflaciformis
4280	12	78																					2											4											
4300	7	62																																	0											
4310	6	46																																	3											
4320	5	41																																	4											
4330	6	31											1																						5											
4340	6	46																																	6											
4350	5	26																					2	2											3											
4360	6	23																																												
4370	9	36														1																			6											
4380	4	11																																											
4390	7	34																																	6											
4400	9	141																					2												7											
4410	8	136																					1												1											
4420	7	77																																	1											
4430	9	106																																	2											
4440	10	81																																1					1							
4450	7	34																																	3											
4460	9	60											1																						5											
4470	8	38																																	3											
4480	5	11																																												
4490	3	8																																											
4500	4	16																																												
4510	4	10																																											
4520	6	24																																												
4530	10	30																																	3					3							
4540	8	27																																						1							
4550	7	24																																						1							
4560	7	48																												1																
4570	11	54																						1											2											
4580	9	72																					1																							
4590	17	119											1										1	2							1				6											
4600	24	184														1							1	1							1				6											
4610	22	173														2								3											4											
4620	16	98							2							1													2		2															
4630	17	109							1				1			1								3					1		1														
4640	13	122																						1					1						1											
4650	6	130							1															4											1											
4660	14	145							1							1								2					2						2											
4670	13	74											1											1																							
4680	12	80																						1																							
4690	11	71														1								1																							
4700	11	80											1			1																															
4710	14	88																						1											1									1	2			
4720	14	86																																											1			
4730	12	47							1														1	1																							
4740	12	46											1																																1			
4750	12	62																																													
4760	19	105							1							1													1																	
4770	12	112	1													3													3																	
4780	13	112																					1	2					2																	
4790	16	147											1			2							1	1					1		2															
4800	14	188																					2					1																	
4810	13	202																					2																							
4820	8	174														1								1																							
4830	11	188																					1	3					1						1											
4840	9	227																					1	3					2						1											
4850	8	114														1																			2											
4860	10	98											1										2																							
4870	11	60																						1											1											
4880	9	121																																	2											
4890	8	116																					1																							
4900	6	124																					1																							
4910	10	162																					1	6					1																	
4920	5	79																																												
4930	5	154																																												✓
4940	5	62																																											
4950	2	11																																											
4960	3	30																																											
4970	4	16																																											
4980	5	10																																											
4990	2	4																					1																							
5000	5	21																																											

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Depth (m)	No. species	No. specimens	Norton sp. 1	Ammodiscus tenuissimus	Buzasina pacifica	Haplophragmoides sp. 2	Haplophragmoides walteri	Bulimina elongata	Haplophragmoides horridus	Oridorsalis umbonatus	Reophax spp.	Spiropsammina primula	Glomospira glomerata	Reophax duplex	Cribrostomoides ovulodes	Reticulophragmium intermedium	Ammomarginulina spp.	Paratrochamminoides gorayskiformis	Paratrochamminoides olszewski	Glomospira aff. serpens	Reophax sp. 2	Conglophragmium irregulare	Verneuilina sp. 1	Subreophax pseudoscalaris	Reophax pyriformis	Paratrochamminoides gorayskii	Rhabdammina linearis	Hormosinelloides guttifer	Karrerulina conformis	Karrerulina convexa	Nodosaria spp.	Trochammoides spp.	Scherochorella congoensis	Reticulophragmium sp. 2 (excavatum)	Ammodiscus cretaceus	Hyperammina spp.	Reticulophragmium venezuelanum	Hormosina globosa	Ammodiscus sp. 1	Subreophax spp.	Bolivina spp.	Uvigerina spp.	Norton spp.	Istrocod	Pseudonodosinella elongata	Praeglobobulimina spp.	Inflated inner
4290	12	78																																				1					
4300	7	62																																										
4310	8	46																																										
4320	5	41																																										
4330	9	31															1																										
4340	9	46																																							1			
4350	5	39																																										
4360	9	23															1																										
4370	9	36																																										
4380	4	11																																										
4390	7	34															1																										
4400	9	141										1																												1				
4410	9	139																																										
4420	7	77																																										
4430	8	188																																										
4440	10	81																																						1				
4450	7	34						1																																			
4460	9	63																																						1				
4470	8	38																																										
4480	5	11																																										
4490	3	8																																										
4500	4	16																																										
4510	4	10																																										
4520	5	24																																							1			
4530	10	30																																						1	1			
4540	8	27										1																														1		
4550	7	24																																										
4560	7	46																																										
4570	11	34																																										
4580	9	72																																										
4590	17	119													1																													
4600	26	186													1	1															1													
4610	22	179																									2				1												
4620	16	98																																										
4630	17	108																																									3	
4640	13	122																																										
4650	6	130																																										
4660	14	145																																										
4670	13	74																																							4		1	1
4680	12	80																																							5			
4690	11	71																																							1			
4700	11	60																																										
4710	14	66																																							1			1
4720	14	56																																							2			
4730	12	47																																										
4740	12	48																																							1			
4750	12	82										1																													1			1
4760	19	106																																								2			
4770	12	117																																										
4780	13	112																																										
4790	18	147						1																																			
4800	14	136																																										
4810	13	202																																										
4820	8	174																																										
4830	11	186																																										
4840	8	227																																										
4850	8	114																																										
4860	10	96															1																											
4870	11	80																																										
4880	9	121																																										
4890	8	119																																										
4900	8	134																																										
4910	10	162																																										
4920	5	79																																										
4930	5	154																																										
4940	5	62																																										
4950	2	11																																										
4960	3	30													1																													
4970	4	16																																										
4980	5	10																																										
4990	2	4																																										
5000	5	21																																										

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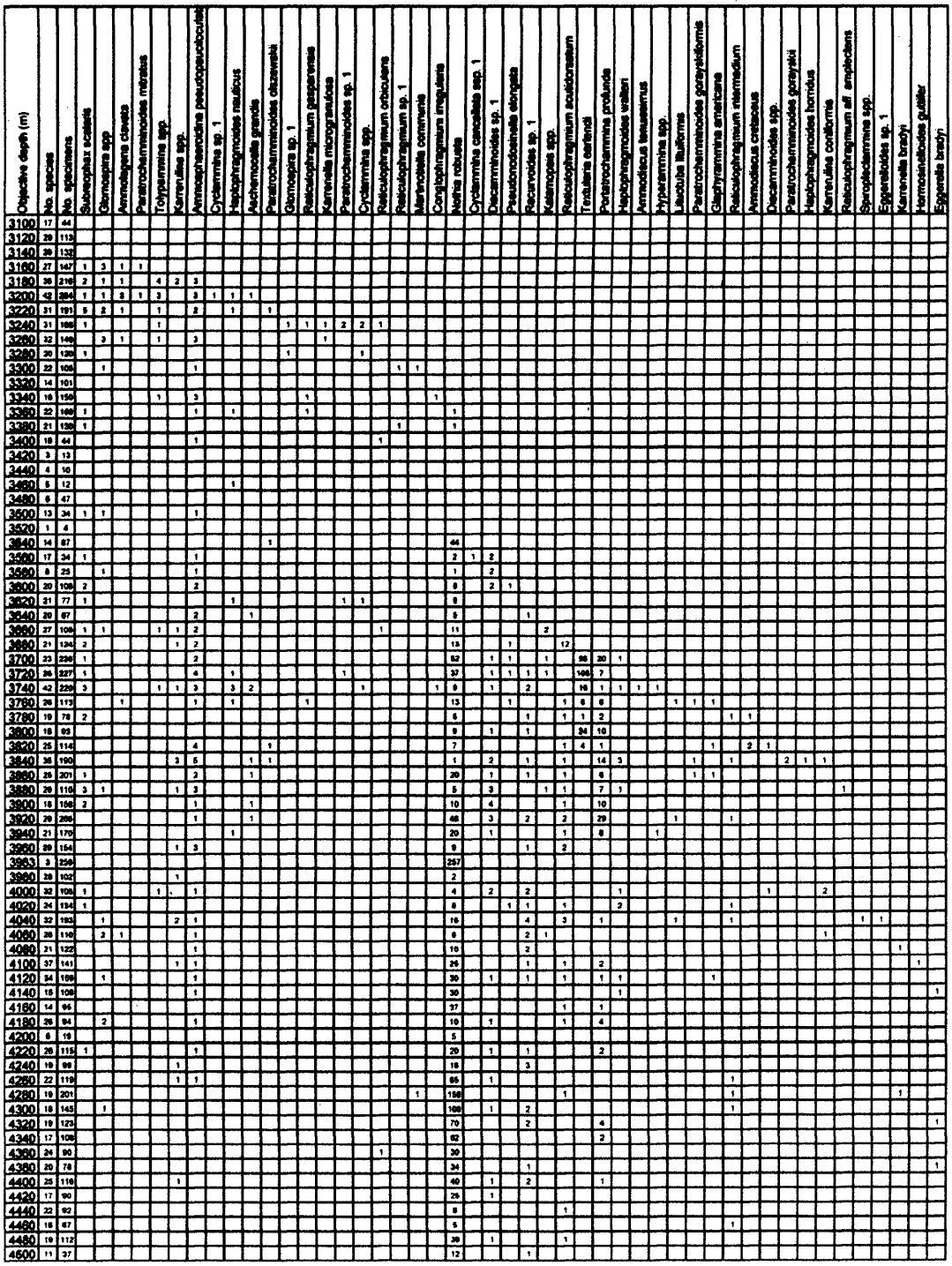
Objective depth (m)	No. species	No. specimens	Undif agglut	Undif calc	Undif plank	Radiolarians	Haplophragmoides bradyi	Saccammina spp.	Rabdammina spp.	Haplophragmoides spp.	Trochammina spp.	Cribrostomoides subglobosus	Glomospira gordialis	Glomospira charoides	Trochammina sp. 1	Ammodiscus latus	Ammodiscus glabratus	Placentammina placenta	Reticulophragmium rotundidorsatum	Recurvoides spp.	Reophanes bowgrani	Haplophragmoides sp. 1	Rhizammina spp.	Reticulophragmium amplectens	Reophax pilulifer	Trochamminoides subcoronatus	Paratrochammoides spp.	Psammosphonella cylindrica	Praesphaerammina spp.	Hormosina globulifera	Reophax spp.	Nothia spp.	Psammosphaera spp.	Reticulophragmium spp.	Bathysiphon spp.	Ammodiscus spp.	Trochammina sp. 2	Kamurolina spiculans	Valvulina fiscilis	Budashevaella multicamerata	Haplophragmoides canariata	Bigenerina spp.	Spiroplectammina primula	Glomospira aff. serpens	Hyperammina elongata	Recurvoides zaspelensis	Subreophax spp.	Glomospira irregularis	Ammodiscus peruvianus	Hormosina glabra
3100	17	44	6				6	4	3	1	6	3	1	1	1	3	1		1	2	2	1																												
3120	29	113	17		1		13	5	36		13	1	3		1					6			4	2	1	1	1	4	2	3	1	3	2	1	1	3	1	1	2	1	2	1	1					
3140	36	135	21				16	5	28	2	7	1	3	2	1					4		1	16	2				2			1	8	5			1			1	2			1	1				
3160	27	147	36					6	36		1		11	2				1		9		1	14	3	1	1	2					9	3	2	5	2									1	1
3180	36	210	36				2	14	46	2	7	3	2	6	2	1						1	48	1	1	1		6		3	1	10	3		6	2			1						1	
3200	42	264	41				4	10	37	2	7	2	6	2	2		2			6	3		48		3	1	2	4	1	3		21	10	1	20	3		2			1		2			2	6	1	1
3220	31	191	48				2	7	36		1		3	6	1	1	2			6	1	1	18		1		2	3	3			14	1		7	6								1	2		
3240	31	188	56	2				6	28	2			10	6						2		1	23	1				4	1	1		3	3		2	4				1	1				2			
3260	32	149	44				3	5	17				5	2	1	1	1			1			18		1		1	4		1		8	1	1	6	4								1			
3280	20	126	37		2			9	23	1			4	2						4			10					5				2	4	1	7	2		1									
3300	22	108	36			10		9	32	1	1					2				1			6	1						1		6	3	1	3	2			2					1			
3320	14	101	36			8		7	19	1			5	7					1				10	1								3	2	1	3								1	1		
3340	18	188	53			26	1	5	37		1			3	2	2							16				1					10		1	10		1		1							
3360	22	166	68	3		33	5	4	37		1		2	2	1	7			1				14			1	3		1			9	1		3		1								
3380	21	130	48	1		16	2	9	20		2	1		2		2			2				16	1			3		1			12			7	3		1	1	1						
3400	19	44	11	2		1	1	1	7		1		1										3									4			2	1		1							
3420	3	13	1	1	2																																									
3440	6	10	1						4						1								3									1													
3460	6	12	6						2				1															1		1														
3480	6	47	0	2	10																																								
3500	13	34	11	1				3	6		1		1		1								2										1		2								1		
3520	1	4	3																									1																
3540	14	97	12	1	2	1		1	6	1	2					2				1			2					1				2		2	3										
3560	17	34	9		1	2	1	1	1	1	5			1		1							1					2	1						1										
3580	6	29	19						2							1												1																	
3600	20	108	24				16	2	10		12			1		1			1	2			4					2				1	1	3	6	3										
3620	21	77	9	2	2		15	4	6	1			3	1	1	1			1	1		1	6									3	3			1									
3640	20	87	15	2			1	1	7					3	2					3			23		1			1		1		10	1		4				1				1		
3660	27	108	30	1			2	2	12	1	2	1	1	4					1	3			12	1	1			1	1			6			5			1					1		
3680	21	124	18					2	20	1		1		2	1					1			13		4			2				20	1		4	2				1					
3700	23	229	17				2	6	4		42			1	1	3				1			6									13	2		1	3						1			
3720	26	227	9				1	2	9	2	16			1		3			3									1				8	1		5	1						1			
3740	42	230	26				3	16	43	3	16	1	2	3	2	5				1			10	2	9		4	2		1	1	16	1		4	2		1			1		1		1	
3760	26	113	18				1	5	19		11		1			3							9		1					1		3	1		2	3				2					
3780	16	78	14	1				6	11		16					1				1			3		3					1		6			1									
3800	16	99	13	1				4	6		11		1		1	1							1					1				2			2									2	
3820	25	114	15				1	3	26	1	4			2		3				1			10	1	1			1				14			5	3									1
3840	36	180	15				2	9	46	1	24			1		2			4	3			9	1	4			2				19	1		1	1			3		1		2			
3860	25	201	18					8	46	1	34		1							1			19	2	3			6				18			3	6				1		1			
3880	20	110	8					3	8	1	25			1					1	1	2		10		1			2				12			3	1			1			1			
3900	16	156	21					5	18		86					2				5	2		9		3	1						12			1									
3920	29	286	7				1	2	19	1	101	2	2		1	3				6	2		10	2	2							6	4	2	2			1			2			
3940	21	170	6	1				6	15	3	46									8	4		18		3			1	1			18	1	2	4						1			
3960	29	154	5	26	1			6	19	1	9				1	1				1	4		2		1			1				5			4									
3963	3	266	0					1																									1												
3980	29	102	3	29	1			1	2	1	1					1				1	2		3									2	1		3									
4000	32	105	6	9				3	25		2	2		1		3				3	4		9	1				3				7			2		1						1		
4020	24	134	16	7				4	37		8				1					1	2		14	1	2		1	7				7			3			1							
4040	32	199	31	2				4	46	2	1	1		1	1					1	4		35		3		2	9				9	1		5		2		2	1					
4060	26	119	24	1	1			2	29	2	3	1	1		2					1	3		10	1	1			2				5			4		1		1						
4080	21	122	34	4	1			2	26		5			2									4	1	2							11		1	1		1	2			1					
4100	37	141	14	14	2			5	20	1	2	1	1		1					2	2		9		1							5		2	1	1					2			1	
4120	34	189	24	1	1			6	23		16					1				1	2		13	1							1	9			2	1	1	1	2						
4140	15	108	31	1	1			1	16		6									2	1	1										5		1		2									
4160	14	85	32		1			1	6	1	7					1				1		2						2								1									
4180	26	98	11	2				1	9		19							1	1	5			1					1				9		3	1										
4200	6	19	9					1			1												1		1							1													
4220	26	116	11	5				2	26		18	1				3				1			3					1				3		1	1	1			1						
4240	19	99	14	1				3	28		13				1	1				2	2		2	1				1				1	1						1						
4260	22	119	11	2				1	11		1		1			1				4			1	2	2							6	2	1											
4280	19	201	5	3				7	3		7				1					3				1	1								1	2											
4300	18	145	5	2	1			3	5		4									1	3				1							1			1										
4320	19	123	1	3	6			3	6		6									1					1							1		1				1						
4340	17	108	0	5	7			1	1		15																							1											
4360	24	90	4	6	4			2	1	1	11	2								2	3		1	1	1							1													
4380	29	76	4	9	4			2	3	2	2									1															1									
4400	25	118	3	7	10		2	2	1	2	13									3	1											3				3				2				
4420	17	80	4	13	4				3		2									2																					1				
4440	22	92	5	28	3			1												1			2																					
4460	18	87	4	29	6			1	2		6									1														1										
4480	19	112	12	20					9	2	1												1									1				1									
4500	11	37	1	8	1			2	3											1	2																								

VENUS-1



VENUS-1

Objective depth (m)	No. species	No. specimens	Cibicidoides mundulus	Cibicidoides havanensis	Cibicidoides spp.	Globocassidulina spp.	Melonis pompilioides	Gyroidinoides altiformis	Nodosaria spp.	Cassidulinella pliocenica	Uvigerina sp.	Cibicidoides crebbsi	Megastomella africana	Ordonella umbonatus	Uvigerina hispida	Uvigerina aff. canariana	Bulimmella sp. 1	Oceanicassidulina spp.	Gyroidina umbonata	Uvigerina spinulosa	Lenticulina spp.	Nonion spp.	Bulimina spp.	Brizalina cf. barbata	Uvigerina mantaensis	Globigerinoides bulloides	Lenticulina americana	Valvulineria pseudoturneyensis	Valvulineria spp.	Globocassidulina subglobosa	Sphaeroidina spp.	Gyroidinoides spp.	Henryaevea americana	Bulimina elongata	Brizalina aff. miles	Cibicidoides grimsdalei	Praeglobobulimina socialis	Bulimina falconensis	Henryaevea mantaensis	Brizalina spp.	Neogloboina longiposta	Gyroidinoides altiformis	Cibicidoides pachyderma	Henryaevea spp.	Bulimina marginata	Globigerinella obesa	Globigerina bulloides	Calapydrax unicavus	scaphopod frag.	gastropod
3100	17	44																																									1	
3120	29	113																																										1	
3140	26	132																																										1	
3160	27	147	2	1																																							1	
3180	26	216	1		1	1	1	1																																			1	
3200	42	884	1						1																																			
3220	31	191								1																																		
3240	31	166									3	1	1																														1
3260	32	148			4	1					1			1	1	1																										1	
3280	26	120										1					1	1																									
3300	27	108														1				1																							
3320	14	101																																									
3340	18	158																																									
3360	22	169																																									
3380	21	130																																									
3400	19	44					1					1			1						1	1	1																			1	
3420	3	13			1									3									6																				
3440	4	10																																									
3460	6	12																																									
3480	9	47			3									1									20	1	1	1																
3500	13	36																										1															
3520	1	4																																									
3540	14	87												2																													
3560	17	34												1																													
3580	9	25																					1																				
3600	20	108																																									
3620	21	77																											1														
3640	20	87									1																																
3660	27	109																																									
3680	21	124																																									
3700	23	239																																									
3720	36	227																						1																			
3740	42	230																																									
3760	26	113																																									
3780	19	78																											1														
3800	16	93																					1																				
3820	25	114																																									
3840	36	190							1																																	
3860	29	201																																									
3880	29	110																																								1	
3900	18	158																																									
3920	29	286																																									
3940	21	170																																									
3960	29	154			13						4					3		4	6		4	1	15				2		3	2												
3963	3	256																																									
3980	28	102			6						4			1		7		6			3	2	9	1			1		1	2	6	1	1								
4000	32	105			1											1						1	1				1		1			2	1								
4020	24	134														3							3																			
4040	32	193																				1								1												
4060	26	110			1																	1																				
4080	21	122			2											5					2																					
4100	37	141	3		1						4			4		2		2				1	1		1								1	1								1
4120	34	189		1	5						1			1		1								1					1						1	2	1					
4140	15	108			1											2																										
4160	14	98		1																										1												
4180	26	98	1		2						3					3													1					1			1	1	1			
4200	6	19			1																																					
4220	26	115			4																1	2	2						1	1					1						
4240	19	89			1																	3																				
4260	22	119		1										1									1	1									1									
4280	19	201			1																	1													1						1	
4300	18	145			1																		1	1						1					1							
4320	19	123		1	2						3							2				2																				3
4340	17	109	1		1				1		1					1		1				2	1				1							3								
4360	24	80			1		1		3		5					1							1							1	3		1						1	1		
4380	20	78			2				4		3										1			1	1		1												1	1		
4400	25	116		1							1					2		2				1		3					1					4							2	
4420	17	80			6						2			1		3					1		13								1					2			1			
4440	27	92	1		3				1		5			1		13					3	2	5				2		2	1				1	2		1		1	1		
4460	18	87			1						7					3					1	1	11						3								1		1		
4480	19	112			3				1		9					1					2	1	3						3								1				
4500	11	37									2												1						1										1			

PLUTAO-1 SIDEWALL CORES

Ammonia sp.
Bathysiphon spp.
Bolivina sp.
Brizalina aff. *inflata* (Heron-Allen & Earland)
Brizalina alazanensis (Cushamn, 1926)
Brizalina cf. *barbata* (Phleger & Parker, 1951)
Bulimina elongata d'Orbigny, 1846
Bulimina falconensis Renz, 1948
Bulimina sp.
Catapsydrax unicavus Bolli, Loeblich & Tappan, 1957
Ceratobulimina alazanensis Cushman & Harris, 1927
Cibicidoides crebbsi (Hedberg, 1937)
Cibicidoides grimsdalei (Nuttall, 1930)
Cibicidoides havanensis (Cushman & Bermúdez, 1937)
Cibicidoides mundulus (Brady, Parker & Jones, 1888)
Cibicidoides perlucidus (Nuttall. 1932)
Cibicidoides spp.
Globigerina bulloides d'Orbigny, 1826
Globigerina praebulloides Blow, 1959
Paragloborotalia mayeri (Cushman & Ellisor, 1939)
Morozovella aequa (Cushman & Renz, 1942)
Globorotaloides permicrus (Blow & Banner, 1962)
Hanzawaia aff. *americana* (Cushman, 1918)
Hanzawaia sp.
Haplophragmoides spp.
Lagena striata (d'Orbigny, 1839)
Lenticulina spp.
Megastomella africana Faulkner, de Klasz & Rérat, 1963
Neoeponides campester (Palmer & Bermúdez, 1941)
Neugeborina longiscata (d'Orbigny, 1846)
Nodosaria anomala Reuss, 1866
Nodosaria sp.
Nonion sp. 1
Nonion sp. 2
Nonion spp.
Nothia latissima (Grzybowski, 1898)
Oridorsalis umbonatus (Reuss, 1851)
Paragloborotalia bella Jenkins, 1967
Paragloborotalia opima nana Bolli, 1957
Paragloborotalia semivera (Hornibrook, 1961)
Plectofrondicularia longistriata Le Roy, 1939
Plectofrondicularia morreyae Cushman, 1929
Plectofrondicularia spp.
Praeglobobulimina sp.
Psammosiphonella cylindrica Glaessner, 1937
Pygmaeoseistron sp.
Rectuvigerina sp.
Rectuvigerina stonei Bermúdez, 1949
Reticulophragmium rotundidorsatum (Hantken, 1875)
Saccamina sphaerica Sars, 1872
Placentammina placenta (Grzybowski, 1898)
Sphaeroidina bulloides d'Orbigny, 1826
Trochammina spp.
Uvigerina aff. *mediteranea* Hofker, 1932
Uvigerina carapitana Hedberg, 1937
Uvigerina spinulosa Hadley, 1934
Uvigerina spp.
Valvulinaria pseudotumeyensis Futyan,1976
Valvulinaria spp.